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# Steam Design Thinking And Innovation: A Collaborative, Interdisciplinary, Authentic Approach To Problem Solving In Mathematics

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STEAM DESIGN THINKING AND INNOVATION: A COLLABORATIVE,  
INTERDISCIPLINARY, AUTHENTIC APPROACH TO PROBLEM SOLVING IN  
MATHEMATICS

by

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A capstone submitted in partial fulfillment of the  
requirements for the degree of Master of Arts in Teaching.  
Hamline University

Saint Paul, Minnesota

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## Dedication

For Niall, for everything.

## Thank yous:

To Kristen Perkins, Dale Leibforth, Peter Bavis, and Isaac Yampolsky: For putting the

“team” in STEAM.

To Kristen Perkins: For being a critical friend, this is your baby too.

To my family: For all the laundry that you folded without me.

To my parents: For . . . well, there aren’t enough words to explain.

To Dr. Jean Strait: For inspiring me at every turn.

To Elizabeth Martin and Anthony Gatto: For the early years.

To RB, NL, ZV, JB, GW, LM, CI, AD & AS: For being the best lo-fi prototypes I could

have asked for.



“If something’s important enough you should try, even if you think the probable outcome is failure.” --Elon Musk,

“We are currently preparing students for jobs that don’t yet exist...using technologies that haven’t been invented...in order to solve problems we don’t even know are problems yet.”

--Richard Riley, Secretary of Education under President Clinton

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## ABSTRACT

Klyn, L. (2018) STEAM Design Thinking and Innovation: A collaborative,  
interdisciplinary approach to problem solving in mathematics.

*How might we design an interdisciplinary curriculum which incorporates collaboration and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?* Inspired by the work of disruptive educators and Stanford University's d.school, this capstone seeks to answer this question with an innovative mathematics curriculum incorporating science, technology, engineering, and art into problem solving experiences that foster: critical thinking, collaboration, leadership, agility, adaptability, initiative, oral and written communication, accessing and analyzing information, curiosity, imagination and resourcefulness. This curriculum suggests six shifts in student learning; from product to process, consumption to production, adult centered to student centered, competition to collaboration, risk averse to risk taking and single discipline thinking to interdisciplinary thinking. The ongoing development of the STEAM DTI curriculum is viewed through a lense of equity aimed at removing barriers to higher-level thinking for traditionally disadvantaged students and is available to everyone seeking authentic problem solving experiences.

## CHAPTER ONE

### Introduction

#### Time for change

After nine years of teaching mathematics, I have learned a few important truths. One, I was born to be an educator because I love working with students and being a partner in their education process. I love to watch as students grow, develop confidence and learn that they have not only the right but the directive to solve the biggest problems facing our local and global communities. Two, students learn and grow when they are challenged with ideas and tasks that are relevant, difficult and approachable. Three, students do not learn and grow when they are too underwhelmed or too overwhelmed. Finally, traditional mathematics education often fails to recognize items one, two and three.

This reflection has led me to the guiding question for not only this capstone project but for the foreseeable future of my teaching career. *How might we design an interdisciplinary curriculum which incorporates collaboration and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?* This question has emerged as I have worked with a team of educators, listened to students and parents and read dozens of books and articles.

As a teacher, I am frequently trying to connect students with a curriculum that does not give students a sense of empowerment and confidence, does not challenge them in meaningful ways and which underwhelms them with irrelevant, boring skills or overwhelms them with computational procedural tasks. Further, much of the

mathematics curriculum isolates the student from other students, from other areas of learning and from creative problem solving. Mathematics curriculum is so often focused on producing students with computational procedural skills that it is failing to deliver students who are genuine problem solvers.

What follows in this chapter is a detailed account of just how I arrived here, and why this project, which involves the development of curriculum for a course called STEAM Design Thinking and Innovation or, STEAM DTI, will not only change the way my students and I define mathematics education, but reshape the way students learn and grow in my classroom.

**Rationale: Students need a new type of mathematics class.**

High school students embark on a pre-scripted mathematics journey. First Algebra, then Geometry. Next comes Advanced Algebra. Many schools have experimented with integrating these pathways, but the outcome remains the same, if students have been fortunate enough to be successful in these areas, then they progress onto more difficult coursework in Calculus, or Discrete Mathematics. Students who have been less successful are funneled into remedial courses or other innovative solutions like online college algebra courses. The most successful high school mathematics curricula produce students who have proficient computational procedural skills, meaning they can solve equations, use formulas, recognize patterns and apply their skills in new but similar contexts. But how well does our mathematics curriculum prepare students to problem solve?

Current mathematics programs across the country emphasize computation and procedure and the results are often good. I believe there is value in these skills. But I believe the conversation should also address additional questions. Should mathematics curriculum produce students who are creative? Should mathematics curriculum produce students who are empowered to solve problems facing their communities such as, “How might we provide senior citizens, living at home, a way to get help when needed without contacting the fire department?” or “How might we reduce the frequency of sewage overflow entering the local lake?” or “How might we encourage healthy masculinity in young children?”

High school has become a frantic mixture of doing everything, but doing it in less time. Forty five to fifty minute periods combined with a laundry list of content standards has students frequently thinking fast and producing projects, homework and tests even faster. Students need the opportunity to slow down and engage in higher quality work. There are few opportunities for students to work on a particular problem for weeks at a time. Sticking with the same problem for a long duration offers students the chance to dig deep, look at all the angles, think about a wide range of solutions, test them and then try again. Slowing down allows students to experience failure then learn from that failure and then fail again and learn again.

In addition to slowing down and engaging in long-term problem solving, students need opportunity to synthesize their learning. The factory model that public high schools employ is outdated and no longer produces students who are prepared to solve the most pressing problems of our world. High school students learn problem solving skills in



isolated disciplines with little or no crossover. This is known as “The Silo Effect.” At Evanston Township High School, where I currently teach, science is learned for 42 minutes before students are shuttled over to math class and then to English class. They develop skills in isolation and are rarely given the opportunity to synthesize their experiences. Many develop a sense that math, for example, is only relevant to math class because it is limited to computation.

The STEAM DTI curriculum being developed aims to make six major shifts in how students experience classroom learning: from product to process, from consumption to production, from adult centered to student centered, from competition to collaboration, from risk averse to risk taking and finally the shift from single discipline thinking to interdisciplinary thinking.

The issue of equity in mathematics education is of personal significance to the author. Students of color are underrepresented in higher level and honors level math courses because they often lack the prerequisite computational skills needed. There is a need for a rigorous problem solving course that sets high expectations and provides problem solving challenges that are accessible and exciting for students of a wide variety of computational skill levels.

### **Rationale: The necessity of collaborative problem solving**

The problems facing our local and global community require problem solvers who not only can fail and learn, but also understand the interdisciplinary nature of true problem solving. As Dr. Morton Shapiro, President of Northwestern University, said to students, “All of the world’s problems that could be solved with a single discipline have

already been solved.” What he meant was that if a problem facing our world could be solved by a scientist alone, it has been solved. We can no longer afford to be specialists working in isolation. Students graduating high school today need to understand that problem solving requires science, technology, engineering, art and mathematics (STEAM) to work in concert. This doesn’t mean students need to be masters of all; they need to be able to recognize and recruit the resources of all. For example, PATH, a global health organization focused on solving some of the most pressing health, sanitation and social problems in the world, recruits interdisciplinary teams of experts to design solutions.

Global concerns such as climate change, resource shortages, emergent intelligence, nuclear technology, terrorism, and internet security & privacy require problem solvers who can collaborate with other problem solvers. Global opportunities such as space travel, international commerce, telemedicine, robotics, renewable energy, and a long list of progressive social issues require opportunity seekers who can collaborate, learn quickly, adapt and learn from failure. High school mathematics curriculums should provide students with the foundation needed to engage with these opportunities and problems.

The need for agile, creative problem solvers is not only needed for global issues. Local communities need people who address problems related to emergency and disaster response, local impacts of climate change, issues of inequity, access to healthy food, transportation and infrastructure. Communities also need individuals who can capitalize on opportunities related to growing economies, changes in demographics and

advancements in technology that will improve their communities. High school mathematics curriculums should be producing students who can contribute to the effort to better their communities through problem solving.

**Rationale: A new mathematics curriculum is needed**

Through this capstone project, I intend to develop an honors level, high school mathematics curriculum that would provide high school seniors with a capstone opportunity. This course, titled STEAM Design Thinking and Innovation (STEAM DTI), is a collaborative, inquiry-driven, process-based STEAM course that would allow students to delve into the lenses and perspectives through which each of the STEAM disciplines (Science, Technology, Engineering, Art, and Math) views problem solving. This course makes that thinking visible and explicit to students so that they can recognize and engage in these different viewpoints. In conjunction with local and global partnerships, students develop networks of experts, stakeholders, and power brokers to shape their understanding. Through locally-sourced and student-generated problems, students will collaborate and apply a variety of methodologies, leverage these networks and utilize a whole brain approach to produce narratives, innovative solutions, and foster creativity.

STEAM DTI will be available to all students regardless of their computational-procedural background and skills, removing one of the most significant barriers facing high school students of color in mathematics. Students who are barred from taking courses like AP Calculus due to pre-requisite requirements will be able to enroll in this course and use their unique skills and expertise to further develop problem

solving skills in authentic contexts. This course will challenge students of all skill sets and levels to think creatively, persist in problem solving over an extended period of time, analyse solutions, engage in testing and user feedback and finally iterate on the process.

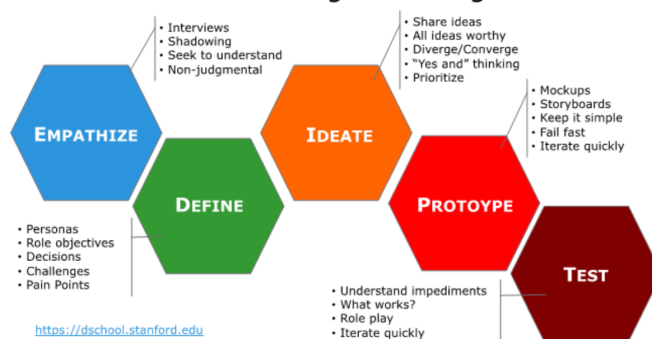
By developing this curriculum, I want to add to the conversation about a broader definition of mathematics curriculum. By sharing the curriculum with other mathematics departments, I hope to hear how others use the ideas in their own classrooms. It is my hope too, that by developing this curriculum, the definition of what is a good mathematics education may expand to include not only computational-procedural skills but real-world authentic problem solving skills as well.

### **Context: Who is calling for this kind of change?**

There are many inspirations for this capstone project. I have spent the last few years listening to stories of parents and students as well as visiting with university faculty. Further, there is high demand from the world's most innovative organizations and companies.

In 2004, Stanford University in California piloted its Design Thinking Program at its new d.school. Design Thinking is a problem solving process that incorporates five key phases:

#### **Stanford d.school Design Thinking Process**



*Fig. 1: The Design Thinking process created by the d.school Image Credit: Stanford d.school (2009)*

Problem solvers (designers) progress through these five phases and repeat or revisit a phase as needed in a nonlinear, fluid, iterative process toward better, more refined, and more user-centered solutions. Stanford pioneered this process in response to the need to prepare a generation of innovators to tackle complex challenges. This Design Thinking approach can be applied in any context including a high school mathematics curriculum like STEAM DTI that aims to offer students a rich problem solving experience.

Northwestern University in Evanston, Illinois recently underwent substantial changes to its undergraduate engineering program. The faculty at Northwestern noticed a growing trend in its incoming freshman students. In conversations with faculty, it was revealed that the students were excellent test takers—they would have to be in order to gain entrance into the prestigious school. Yet, although they were excellent test takers, they were consistently unable to collaborate effectively, communicate their ideas, and recover from and learn from failure. These students represented the best and the brightest that the nation’s high schools had produced, yet they were totally unprepared to work together to solve real world problems.

In response, Northwestern redesigned its entry level engineering course to meet these needs. Called, “Design Thinking and Communication” and based on themes similar to those at Stanford’s d.school, DTC offers students a chance to tackle large problems in their communities in a collaborative setting. Students experience failure that, instead of ending the project, offers new learning and better designs. DTC has grown to a

multi-year program at NU called the Manufacturing and Design Engineering (MaDE) program. Design Thinking and Communication has spun-off courses title, “Designing Your Life” and “Design Thinking and Doing”.

The demand for problem solvers is not limited to the universities. In an address to shareholders, Jeff Bezos, founder, chairman and CEO of Amazon, explained that he asks three questions of potential candidates. First, “will you admire this person?”, second, “will this person raise the average level of effectiveness of the overall group they’re entering?” and finally, “along what dimension might this person be a superstar?” These questions underly Amazon’s practice of hiring creative, innovative, game-changing collaborators who are not merely specialist but who bring something extra to the table.

Along with Amazon, Google is also looking for creative problem solvers. Here is an excerpt from google’s “how we hire” page:

*There’s no one kind of Googler, so we’re always looking for people who can bring new perspectives and life experiences to our teams. If you’re looking for a place that values your curiosity, passion, and desire to learn, if you’re seeking colleagues who are big thinkers eager to take on fresh challenges as a team, then you’re a future Googler.*

The page goes on to state that the company looks for candidates with “A broad, interdisciplinary background” (Google, 2018).

Even within our own mathematics education system, the conversation about what should be taught has shifted to include skills that go beyond computations, memorization and application. In the 1990’s, the “Standards and Accountability” movement marked a

shift toward a more unified definition of what should be taught in mathematics and how learning should be assessed. The development of the Common Core State Standards for Mathematics (CCSSM) was a response to this trend. The CCSSM attempts to guide participating states in designing curriculum that will offer students the skills necessary to succeed in the twenty-first century (The Corporation for Public Broadcasting, 2002). A primary focus of the CCSSM is to narrow the focus and generate a list of what should be taught in the traditional mathematics courses such as Algebra, Geometry etc. Along with a laundry list of what skills and content students should master, the CCSSM detailed eight standards of mathematical practice that should be developed in students:

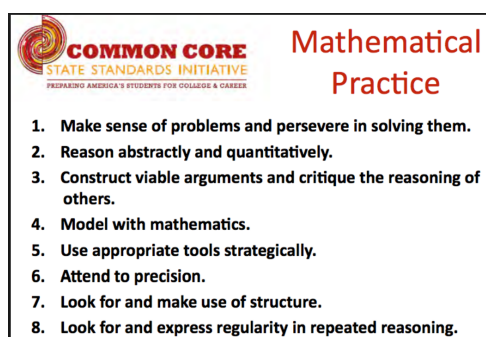


Fig.2 Standards of Mathematical Practice from [www.corestandards.org](http://www.corestandards.org)

Even the states that did not adopt the CCSSM but which did redevelop their content standards included a similar charge to emphasise these types of skills. These skills should not be developed solely through computational and procedural practices. Making sense of problems for example, should extend beyond making sense of an equation and include making sense of the problems facing the community or the classroom. Constructing viable arguments should not only include geometric proof but also using research and evidence to support your proposed solution to a problem. Using

appropriate tools should not be limited to selection of a correct formula but should also include knowing how to synthesize and visualize data to communicate your ideas.

Perhaps what drives this project most, however, is my own personal experience teaching mathematics and feeling desperately as if something was missing. I have taught algebra, advanced algebra, pre-calculus, calculus, Advanced Placement Calculus and remedial math. In each and every year, with each and every student, I have participated in what feels like a battle. Students are not able to connect the work in the mathematics classroom to their individual realities or to any of their other learning. To many students, math is to be worked on, in isolation, for a few minutes a day and only because someone told them they had to.

Mathematics departments across the country are successfully producing curriculum that engages students in computational procedural skill building and visual and spatial reasoning. But they are missing the chance to offer real problem solving opportunities to students because real problem solving often does not include an emphasis on computing or formulas. I believe my high school's mathematics program should provide a curriculum that offers multiple kinds of mathematics learning experiences. Courses such as advanced algebra and pre-calculus should be offered along with courses in authentic problems solving such as STEAM DTI. This balance of learning opportunities would develop students' computational procedural skills but would also develop skills in key areas such as critical thinking, collaboration across networks, leading by influence, agility and adaptability, initiative and entrepreneurship, oral and



written communication, accessing and analyzing information, curiosity and imagination and finally, resourcefulness.

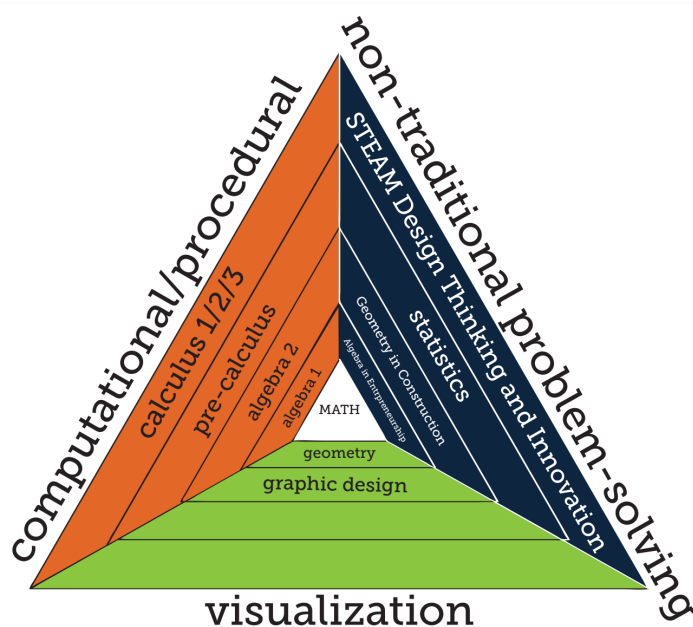


Fig. 3 The components of a balanced mathematics curriculum Image Copyright: Klyn 2017

### **Context: Where does this new math course fit into the picture?**

I began teaching a course called STEAM Design Thinking and Innovation this past year as an experiment supported by my school's administration, my department chair, Northwestern University, as well as Gordon Segall of Crate and Barrel. In my early conversations with students and their parents, a common theme is that the STEAM Design Thinking and Innovation course is filling an important gap that students have in their educational experiences. Students report that they have never had an opportunity to collaborate in problem solving to the extent in which this course requires. Further, they have never had the opportunity to engage in problem solving that requires the amount of time and persistence that the problems in this course require. Students have shared with me that in their course work, they are typically given a scripted path along which they

complete tasks and eventually produce the required artifact (presentation, paper, test etc).

In contrast, this course engages them in problem solving that is not scripted for them.

They must discover the path forward for themselves.

Parents have also taken notice of the difference in this experience. A common theme in my conversations with parents is, “I wish there was a class like this when I was in high school, it would have prepared me for college or my career.” Throughout the year we have engaged members of the community to offer feedback and mentorship to the students and a common theme in conversations with these individuals is, “I wish more students would take a course like this before I hire them.” These adults are comparing the educational experiences of their children to their own and are seeing a need too!

Additional evidence that this innovative math curriculum is serving students comes from the other attempts my school’s mathematics department has undertaken in order to reshape the mathematics experiences of students. STEAM DTI fits into an innovative approach to mathematics that my school is piloting. By offering students courses that deliver the traditional skills in combination with an overarching, real-world theme. The STEAM DTI course is intended to be a capstone mathematics class for students who have followed this enhanced curriculum pathway.

Geometry in Construction offers students the opportunity to learn a standard geometry curriculum while building a house that will be installed in the community and sold to a family qualifying for housing assistance. The house is built over the course of the academic year. Students alternate between days of building and days of classwork. Each unit is based on a theme that is then applied in the construction of the house. For

example, a unit on right angles corresponds to the installation of the staircase. Students earn dual credits in math and engineering.



Fig. 4 Students frame the first level of the 2017-2018 GiC House

*Photo courtesy of Wildkit Construction.*

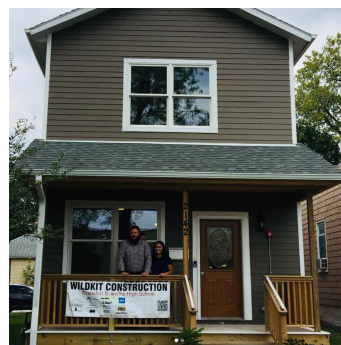


Fig. 5 Co-teachers Maryjoy Heineman and Matt Keiser celebrate

*the installation of the 2016-2017 GiC house.*

*Photo courtesy of Wildkit Construction*

Algebra in Entrepreneurship offers students the opportunity to start and run small businesses in the context of their beginning algebra class. Students in this course earn dual credits in math and in business finance.



Fig. 6.: A team of ETHS students presented their UFO Portable Chargers business to make small portable reserve batteries for cell phones. They pitched their concept “Shark Tank”-style, inspired by the reality entrepreneurship TV show. (Photo credit: Lynn

*Trautmann, LTPPhoto Evanston)*



Fig. 7. Co-teacher Chris Manilla congratulates the winners of the end of year showcase (Photo Credit: AiE)

STEAM DTI is currently in its early and experimental years. Future mathematics curricula planned by the department include, “Advanced Algebra in Social Justice”, “Advanced Mathematics in Coding” and “Statistics and Data Visualization”.

### **Summary**

In summary, I am passionate about providing learning opportunities to students that are life-changing and world-impacting. Not only is it imperative for students that a curriculum be designed which will challenge them, allow them to build collaboration skills, connect them to global and local problems and opportunities and offer them real-world experience, it is imperative for local and global communities that our high schools produce students who are prepared to engage in the areas of greatest need and opportunity. My capstone project will explore the question: *how might we design an interdisciplinary curriculum which incorporates collaborative and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?*

Chapter two will offer a detailed synthesis of literature supporting the need for a mathematics curriculum that focuses on interdisciplinary, collaborative problem solving. The review of literature will also focus on issues of equity in mathematics education and how the STEAM DTI curriculum could support efforts to provide equitable educational opportunities. Chapter three will lay the foundation and provide the rationale for the curriculum that will be developed. Chapter four will summarize the curriculum work and offer reflections on future development. Throughout this capstone project, there will be a clear passion for students and student learning and a vision of hope for producing high school students who are ready to tackle and solve the world’s greatest problems.

## CHAPTER TWO

### Literature Review

#### Overview

In the groundbreaking book, *The Flat World and Education: How America's Commitment to Equity Will Determine our Future*, Darling-Hammond (2012) notes that 70% or more of U.S. jobs require the following qualities: collaborate with others; investigate, define and solve problems using a variety of tools and resources; communicate effectively; design and manage work so that it continues to improve; find, analyze and use information in a variety of forms and contexts and develop new ideas and products. In a report published by *The Economist* and sponsored by Google, the most sought after skills in today's economy are defined as: problem solving, critical thinking, collaboration, communication, values and ethics and a capacity for life-long learning (Google and The Economist, 2015). These two lists of essential skills come from two very different viewpoints yet they intersect and imply a need in education.

The work our students will be asked to do will continue to change and students must be prepared to adapt to the needs of jobs and careers that are not even reality yet (Darling-Hammond, 2012). Our high school students must have access to rigorous curriculum that will prepare them for this future. *How can an interdisciplinary curriculum incorporate collaborative design-thinking to equip all students to tackle authentic, complex problems of critical relevance?*

This review of the literature will explore the four themes that inspired this curriculum project which is the creation of a new course titled “STEAM Design Thinking

and Innovation.” Each theme represents an area of need within mathematics education that will be addressed in this new curriculum. First, the review will focus on the need for interdisciplinary, or STEAM, education. Second, the need for development of creative, problem-solving skills and the benefit of the Design Thinking process will be reviewed in detail. Third, the review will focus on the need for collaboration in problem solving. In the fourth and final theme, the review will turn to issues of equity within mathematics education. These four themes lay the foundation for the STEAM Design Thinking and Innovation course that is in the early stages of development at Evanston Township High School in Evanston, Illinois. The course is offered in the mathematics department with the goal of offering opportunities for students to engage in higher-level thinking and problem solving as a capstone to their STEM education. Additional outcomes of the course include building soft skills often referred to as 21st century skills which, in addition to collaboration, critical thinking, creativity and problem solving, include skills such as leadership, self-motivation, responsibility and time management. This literature review and this project will focus on the development of the former, however it is anticipated that the latter will also develop as a result of the opportunities presented in the course.

## **STEAM**

### **Overview of STEAM**

The fusion of arts into STEM education yielded the acronym STEAM, for STEM + Arts. The STEAM movement within education seeks to unsilo the learning and tie the disciplines together within the learning experiences (Catterall, 2017). STEAM brings

together the “how” and “what”, and connects them with the “why”. It is an educational approach to learning that uses the disciplines as “access points for guiding student inquiry, dialogue and critical thinking” (Riley, 2014). Collaboration and an emphasis on process-based learning are the key aspects of STEAM education (Heinrikson, 2017).

### **The Importance of Interdisciplinary STEAM Education**

The problems and opportunities addressed by thinkers today require 21st century students to move beyond single-disciplinary content, and specialties. Creative thinkers who can work across disciplines are needed in order to meet the needs of global and local communities (Mishra, et al., 2013; The Partnership for 21st Century Skills, 2007). Prominent leaders in fields like math and science are also highly creative and interdisciplinary individuals. These exceptional thinkers are actively and deeply influenced by interests in music, performance, visual arts and more (Dail, 2013; Eger, 2013). Catterall (2002) asserts that the future of innovative problem solving in STEM fields relies on rethinking the distinction between disciplines seen as “creative” like the arts or music, and STEM disciplines seen as logical-mathematical. Teaching and learning that integrates arts with STEM is essential for students. Evidence suggests that the connection between art and science is innate in effective, innovative professionals in STEM fields (Mishra, Henriksen, & the Deep-Play Research Group, 2012; Root-Bernstein, 1999).

The National Academies of Sciences, Engineering, and Medicine (2018) conducted an extensive research project which investigated the impact of interdisciplinary learning in higher education. The study draws several important

conclusions for higher education. First, integrating learning produced several outcomes for students including: increased critical thinking abilities; higher-order thinking and deeper learning but also increased content mastery, problem solving, teamwork and communication skills, as well as improved visuospatial reasoning, and general engagement and enjoyment of learning. Second, the study suggests that integrating STEM into arts could lead to improved literacy in technology which would provide additional tools for practitioners of the humanities. The study also notes that integrated learning also leads to greater development of key social skills needed for twenty-first century employment such as empathy, resilience, and teamwork; improved visual diagnostic skills; increased tolerance for ambiguity; and increased interest in communication skills. But perhaps the most relevant finding as it relates to higher education is the following statement from the study:

Employer surveys consistently show that employers are asking for graduates with more than deep technical expertise or familiarity with a particular technology. They are looking for well-rounded individuals with a holistic education who can take on complex problems and understand the needs, desires, and motivations of others (The National Academies of Sciences, Engineering and Medicine, 2018).

While the study conducted by the National Academies of Sciences, Engineering and Medicine focuses on higher education, the implications for high school education are clear. Employers are searching for individuals that have a wide variety of technical and social skills. Because of this demand, higher education is adapting to provide a more



integrated educational experience for college students. High school education must also adapt and provide students a proper foundation in these skills so that if they choose to attend college, they are prepared to improve these essential skills. For students not attending college, high school must prepare them with the skills needed to ensure they are prepared to meet the demands of today's employers.

If integrating learning is so important, why has k-12 education struggled to make the necessary changes? Sousa and Pilecki (2013) note that there is a general misconception about the arts and the sciences. The public often sees art and science as having the opposite characteristics requiring thus requiring students to learn the skills in isolation'. The authors summarize public opinion in the following table:

<b>Table 1.1</b> Public often sees STEM and the arts as having opposite characteristics.	
<b>STEM</b>	<b>Arts</b>
Objective	Subjective
Logical	Intuitive
Analytical	Sensual
Reproducible	Unique
Useful	Frivolous

*Table 1 Image Copyright Sousa & Pilecki, 2013*

However, the true goal of both artist and scientist is to discover. Combining all the disciplines and encouraging the student to make discoveries promotes development of creativity, as well as boosting cognitive and social growth (Sousa & Pilecki, 2013).

Fulton and Simpson-Steele (2016) define the similarities between the problem-solving processes of the arts and the sciences:

*Common Processes in the Sciences and Arts*

<b>In the Sciences...</b>	<b>Common Processes</b>	<b>In the Arts...</b>
Data collection	<b>Noticing</b>	Observation
Curiosity	<b>Wondering</b>	Imagination
Experimentation	<b>Exploring</b>	Rehearsal
Design	<b>Visualizing</b>	Composition
Explanation	<b>Communicating</b>	Performance/Exhibition

*Fig. 8 Copyright Fulton & Simpson-Steele (2016)*

The table above highlights the fact that although the actions taken may differ, the goals of the scientist and the artist are often the same. For example, in addressing crime in a community, a scientist might gather data on the number of crimes and the nature of those crimes while an artist might speak with community members to determine the emotional impact of the crimes. In each case, the goal is to discover what there is to know about the problem (Fulton & Simpson-Steele, 2016). Sousa and Pilecki (2013) echo the assertions of Fulton and Simpson-Steele, describing how art encourages students to view a problem through a subjective lense while science encourages an objective one (Sousa & Pilecki, 2013). Exposing the student to both the process of the scientist as well as the artist helps them use both to make informed decisions while solving problems. This is the ultimate goal of interdisciplinary STEAM education programs.

Henrikson (2017) observes that the new STEAM trend has tended to frame itself as solely about arts integration. Math and science teachers may not have artistic training or may not identify themselves as “artistic”. In the reverse, arts teachers may lack confidence and understanding of how to build STEM into the arts. A different view of STEAM is needed, one that does not simply combine the disciplines it spans them and

offers “entry points across contexts”. This view of STEAM focuses more broadly on several tenets which the author identifies as, “interdisciplinarity, creativity, authentic or real-world learning, and project-centered thinking”. Offering STEAM education in this way requires a curriculum that allows for “messy, creative practices within the already messy and challenging contexts of teaching”. Henrikson (2017) then suggests that combining STEAM with Design Thinking may offer this context. The case for including Design Thinking in STEAM education will be made in the next portion of the literature review (Henrikson, 2017).

There is agreement among the authors that while conventional wisdom suggests education should be separated and contained in individual classrooms where students learn sets of skills in isolation, offering interdisciplinary educational opportunities benefits all students. Because the processes of each discipline are similar or overlapping, integrating them offers students a learning experience that speaks to innate problem solving instincts. The development of the STEAM Design Thinking and Innovation curriculum will focus on offering students the opportunity to experience these similar problem solving processes, to compare and contrast them and ultimately to help them work in interdisciplinary setting in their future endeavours.

### **STEAM and Creativity**

Many authors argue that integrating the arts and sciences yields benefits to students. In the words of scientist and educator Carl Sagan, “it is the tension between creativity and skepticism that has produced the stunning and unexpected findings of science”. We must offer our students learning opportunities that encourage them to

identify themselves as creative individuals. Integrating artistic skills such as sketching, performing and writing into problem solving enhances the students' experiences (Sagan, 1986, p.73). The art aspect of STEAM has often been referred to as creativity in STEM education (e.g., Land, 2013; Kang, Jang, & Kim, 2013; Kim et al., 2012; Madden et al., 2013; Sousa & Pilecki, 2013). There are many advantages to integrating the arts and sciences. In addition to fostering creativity, students demonstrate cognitive growth and increase long-term memory capabilities (Sousa & Pilecki, 2013).

Creativity is innate (Andreasen, 2005), but for many students especially at the high school level that creativity is latent because it hasn't been fostered. Students can unleash creativity and innovation with simple practice and encouragement. Kelley and Kelley, founders of Stanford's Design School, found that high school students in particular view creativity as isolated to the visual and performing arts and not present in mathematics classes (Kelley & Kelley, 2015). When observed as a whole, the literature supports not only fostering creativity in our students, but fostering it through interdisciplinary learning.

## **Problem Solving and Design Thinking**

### **Overview of Problem Solving**

Mathematics coursework, with few exceptions, focuses on computational procedural skills. Students are exposed to equation solving, graphing, and scenario problems that do not have relevant connections, but are intended to build skills in isolation. The emphasis on preparing students for standardized tests and Advanced Placement tests has yielded strong results as students are taking more and more advanced

mathematics classes in high school. Yet, students do not have many opportunities to tackle problem-solving opportunities that have an authentic, immediate context. Students need opportunities to tackle big, juicy, problems that allow them to delve into the many layers that make up the complex issues that matter to them and their communities. This experience doesn't just prepare them for the "real world" after high school, it allows them to engage in the real world they currently live in. Engaging in sustained efforts to untangle complex problems helps students develop persistence in problem solving (Boaler, 2017). By leaving problem solving more open-ended students must navigate the path themselves. A necessary component of the discussion of authentic problem solving is the need for creativity and innovation. Students need opportunities to recognize and develop their own creativity so that the solutions they generate for the problems and opportunities they are addressing will be truly innovative.

Design Thinking is an approach to problem solving used in Human Centered Design and cutting-edge design firms. Additionally, Stanford University and Northwestern University have each integrated Design Thinking into their design and engineering programs. Design Thinking in high school classrooms would give students a new way to think about what problems are and what it means to solve them. Using the Design Thinking approach fosters creativity and encourages student to be innovative in their solutions.

### **Current Standards for Mathematical Practice**

When completed, the STEAM Design Thinking and Innovation curriculum will offer students the chance to engage in problem solving opportunities that are designed to

build important skills. There is a growing movement in education to emphasize in-depth instruction of the most essential skills, rather than simply covering all the items in a particular textbook. This has been analogized by many as converting our students' educational experiences from "a mile wide and an inch deep" to "an inch wide and a mile deep". By focusing on depth in our students' education rather than breadth, we can not only improve student motivation, but also retention. To focus, we need to distill the standards into what Ainsworth refers to as "power standards". By asking, "what essential understandings do our students need?" and, "which standards can be incorporated into others?" educators are creating deeper learning experiences for students (Ainsworth, 2003).

This notion of "power standards" has lead educators in mathematics to create working definitions of the most essential skills that students must develop through their mathematics education. According to the National Council of Teachers of Mathematics states, that the Common Core State Standards (CCSS) were created to standardized both mathematics and English Language. They were developed by the Council of Chief State School Officers (CCSSO) in cooperation with the National Governors Association (NGA). The standards for math include both content standards and process standards known as standards for mathematical practice. The standards outline what each student should know and be able to do at the conclusion of each grade or course level. The aim of the standards is to identify and define both skills and knowledge that all students require to succeed in college, career, and life, regardless of where they live (NCTM, 2018). The collection of required standards and skills is not new to mathematics education, however

the addition of the standards for mathematical practice was new at the federal level. The table below summarize the descriptions of three of these standards which will be addressed in the STEAM DTI curriculum:

Make sense of problems and persevere in solving them	“Students can explain to themselves the meaning of a problem and looking for multiple entry points to a solution or solutions. They analyze givens, constraints, relationships, and goals. They can make conjectures about the meaning of the solution(s) and plan a solution pathway rather than simply jumping into a solution attempt. The students can consider analogous problems. They monitor and evaluate their progress and change course if necessary.”
Construct viable arguments and critique the reasoning of others	“Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is.”
Look for and express regularity in repeated reasoning	“Mathematically proficient students maintain oversight of the process, while attending to the details of a problem. They continually evaluate the reasonableness of their intermediate results.”

Table 2. Adapted From: *The Common Core State Standards* <http://www.corestandards.org/Math/Practice/>

The standards for mathematical practice describe students who are critical thinkers, thoughtful critics of themselves and others and resilient problem solvers. Mathematics education typically promotes these qualities in the context of computational, procedural, and theoretical mathematics. However, there is a notable lack of contextual experiences for students in mathematics classes that would further develop these skills (Boaler, 2016). The STEAM Design Thinking and Innovation curriculum will offer students the chance to engage in problem solving opportunities that are designed to build these skills as well as collaboration skills and creativity.

## **Developments in Mathematics Education**

Research conducted by Gaertner, Kim, DesJardins, and McClarty (2014) suggest that computational procedural mathematics courses completed in high school have a positive impact on college success. However, the impact on career advancement is significantly less. This indicates that perhaps mathematics departments should reconsider the current “everybody takes Algebra 2” approach. Algebra 2 enrolment has significantly increased over the last several decades from 45% of high school students to 70% of high school student. This increase is largely due to the standards movements and a wider emphasis on students completing college entrance exams such as the SAT and ACT (Gaertner, Kim, DesJardins, & McClarty, 2014).

Marzano, Kendall and Gaddy (1999) cite research by the Mid-continent Regional Educational Laboratory which concluded that the current laundry lists of standards required of students would take nine additional years of schooling to reach mastery. The authors point to the need for the education community to make difficult decisions about what is essential learning and what are the crucial learning experiences that students must engage in before their graduation (Marzano, Kendall & Gaddy, 1999). Mathematics programs are not exempt from this responsibility. Our students need mathematics curriculums that emphasise the most necessary skills and knowledge and optimize their time in the classroom.

There is an observable shift occurring in the ethos of educational philosophy as schools reflect on the overall preparedness of students to participate in the workplaces of the world. The question being asked is: Is it enough to simply prepare them for college?



Schools like California's High Tech High, the Met network of schools and countless other schools engaging in disruptive innovation have broadened their missions to include preparedness for active engagement in the world. Common themes at these schools include a focus on the skills that students need to be successful and to thrive in a global knowledge community. All students need to be able to create, innovate, collaborate, adapt, communicate, analyze information and above all be curious and imaginative. Another common theme is a shift away from acquiring a body of facts and procedures in favor of developing the skill to adapt and acquire needed information. This emphasis on fostering "lifelong learning" allows students to adapt to new challenges rather than recite what has been memorized. A final recurring theme in these schools is an understanding that students of today may be motivated in a completely different way from students of past generations. They are fully integrated with technology, comfortable multitasking and seek immediate gratification. While they thrive with adult mentorship, they are averse to adults who do not value their abilities and approach them from a position of power. Students today seek opportunities to be creative and make an impact (Wagner, 2014).

### **Creativity and Innovation in Problem Solving**

Unfortunately, for many stakeholders the mathematics classroom is not seen as a welcoming place for creativity, nor do they see how mathematics are connecting outside of the classroom. Students need to tap their own creativity in order to navigate their daily lives as well as their future endeavours. One of the greatest tragedies for many math teachers is encountering students who identify themselves as "not creative" or who see

mathematics as a safe way to avoid being creative. Mathematics programs have developed a (often deserved) reputation for promoting rote memorization of facts and processes. Students often see math class as a struggle to remember rather than an opportunity to create. The difference between math and other subjects is not due to the nature of math. Widespread misconceptions about math have students, parents and teachers believing that math is a subject of procedures, rules, right and wrong. Parents who hated math in school still argue for traditional math because they believe it's the way it has to be, that the unpleasant nature of math education is due to the unpleasant nature of math itself (Boaler, 2016).

In addition to creativity, curiosity has suffered under the traditional mathematics curriculum. Students are leaving our schools less curious than when they entered them (Couros, 2015). They graduate masters of just one thing- school. Couros cautions that schools may be approaching irrelevancy if they do not adapt and innovate in order to provide students with learning opportunities that allow them to flourish rather than constrain them with rule and prepare them for tests. In further emphasis of the point, Couros quotes Dr. J. Martin, as saying “No teacher has ever had a student return to them and say that a standardized test changed their life.” Mathematics education has a responsibility to not only prepare students for the entrance exams that will allow them access to higher education, but it must also prepare them to be successful thinkers and innovators! Couros asserts, “Innovation is not reserved for the few: it is something we will all need to embrace if we are to move forward”. Innovation is creating something new and better. We need innovation with in our math education system and we need to

offer students the opportunities to be innovators (Couros, 2015). Because creativity is innate in all students, schools need only to offer opportunities for students to tap that creativity then allow it to flourish. School curriculum and school itself can be reimagined in order to accomplish this.

Couros has re-imagined school for today's learners. The following image from the book compares the characteristics of traditional school to Couros' imagined experience for students:

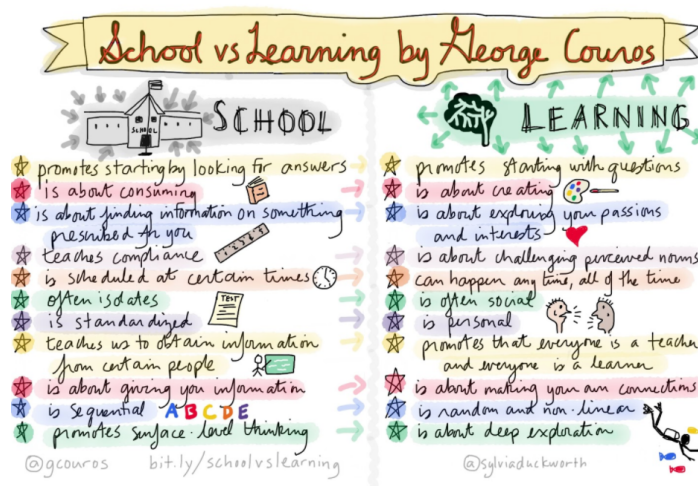


Fig. 9. School vs. Learning Image copyright, Couros, 2015

The image shared by Couros highlights an approach to education that favors inquiry and creativity over remembering and repeating. In developing new mathematics curriculum such as the STEAM Design Thinking and Innovation course inquiry and creativity are central themes that present themselves in each unit, project and lesson.

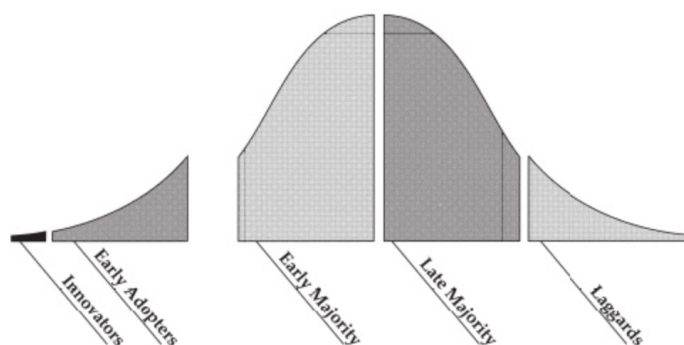
A breadth of research has been offered which suggests the benefits of creativity. Creativity has a deep impact on problem solving because at its best, it includes divergent thinking (Madden et al., 2013; Sousa & Pilecki, 2013). Divergent thinking leads to multiple solutions. Creativity leads to innovation which often results in a product,

students do not simply think something new, they make something new (Sousa & Pilecki, 2013). Students need opportunities that allow them to fostering creativity through experiences. Research has demonstrated that problem solving opportunities requiring creative thinking yielded several positive results. First, students' self-reflection capabilities grew over time as a result of seeking multiple solutions to a problem, critiquing the possible solutions and considering things such as feasibility, impact, opportunity and novelty (Autry & Walker, 2011). When students engaged in problem solving that required creative thinking, they strengthened collaboration skills (Crow, 2008). Finally, when creative thinking was the focus of problem solving, students were engaged in sustained use of advanced thinking skills such as analysis, metacognition, planning, tracking progress and evaluating the effectiveness of one's efforts (Hargrove, 2011).

There are many prescriptions for developing creativity in students. In the book, "Cultivating Curiosity", Ostroff (2016) distills the thinking into the following list: promote exploration and experimentation, allow autonomous and effortless learning, embrace intrinsic motivation, bolster imagination, support questioning, make time, and create curiosity habits. Some of these are nominally supported in today's mathematics curriculums. For example, innovations in curriculum have led to more student-driven inquiry and questioning, though still with in a strictly prescribed set of skills and standards. Others from the list are eschewed completely, such as making learning effortless and autonomous and embracing intrinsic motivation (Ostroff, 2016). Few of the items are made central to the course paradigms. The development of the STEAM

Design Thinking and Innovation centers around each of the ideals central to the cultivation of curiosity in students.

Along with this emphasis on creativity, there is new interest in classroom experiences that incorporate innovation. Innovation refers to the creation of something that wasn't there before. Innovation opportunities take students beyond remembering and application and even beyond synthesis. Innovators are visionaries, seeing things with fresh eyes and taking risks in trying new things. In writing "Crossing the Chasm", G.A. Moore uses the following image to describe the adoption of technological advances, but the image and its descriptions show how people and systems adopt change:



*Fig. 10 How Change is Adopted Copyright G.A. Moore 2014*

Innovators are those who lead the change, create new products, imagine new solutions. Early adopters follow in the footsteps of the innovators and are quick to see a new solution as beneficial. The early majority is comprised of those who see the success of the innovators and the early adopters and quickly sign on themselves. The late majority are more reserved, waiting to see continued success and searching for verification before following the change. The laggards are those that refuse to the very end to adopt the innovation even though the vast majority of people have (Moore, 2014). It is the innovators that drive the change, introduce new solutions and offer novel ideas that

eventually become mainstream. High school students need learning opportunities that allow them to see themselves as innovators.

Wagner (2012) writes in *Creating Innovators: The Making of Young People who Will Change the World*, that schools are “deeply and inherently” protective of what E.D. Hirsch deemed, “cultural literacy”. Cultural literacy can be thought of as the essential knowledge required to be a functioning adult in society. Schools hesitate to deviate from a formula that has transmitted the required information for decades and produced acceptable levels of cultural literacy in its students. The problem with this, asserts Wagner (2012), is that this process of transmitting content from teacher to students can dramatically impact creativity and curiosity in students. The education system in general, and more specifically math education, fails to offer opportunities for students to ask generative questions, to innovate or to make something that wasn’t there before. Research shows that even the best of the best are graduating from universities with a lack of conceptual understanding of the mathematics they have been learning for years (Wagner, 2012). If students are learning facts but not the big ideas behind those facts, then it is imperative that a solution, in the form of a new curriculum, be offered to students so that they have the opportunities to put theory into practice.

Wagner (2012) describes the current system of education as consumption focused. Too often, students are engaged in passive learning where they encounter disjointed bits of information but do not have the opportunity to use their knowledge to create (Wagner, 2012). Students need the opportunity to see themselves as creators, develop skills and competencies and acquire the knowledge they need as they need it. The ideas of creating

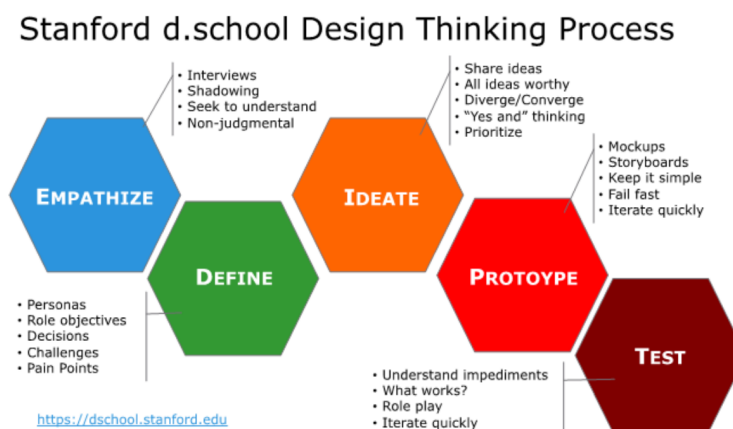
something new, seeking needed knowledge and developing competencies is empowering for students because they become the driving force of their education. In a classroom that promotes these ideals, it would not be unheard of to find the students doing far more of the work involved in their education than their teacher. The teacher's role becomes that of a mentor and a guide, someone who can offer objective feedback based on their experience and expertise in learning.

### **Overview of Design Thinking**

The question of how to foster innovation by allowing creativity and curiosity to flourish within the context of rich problem solving and collaboration may find its answer in design thinking. Design thinking provides one possible framework that is useful for students who seek rich problem solving experiences. Design can be thought of as process for creating something such as a product, a system, an environment, or a service. This process is both an art and a science based in human-centric problems (Buchanan, 2001). Creativity, curiosity and interdisciplinary thinking, real-world, project-driven emphases, are central to the design process. With its nonlinear, open-ended nature, the phrase “design thinking” has become popular, because it offers a model which teachers and learners might follow and adapt to their own situation. Design thinking presents a clear process with phases and practices that link creativity with analysis (Henriksen, 2017).

The phrase “design thinking” refers to thinking skills, mindsets, processes and practices which designers use to formulate new ideas they then use to solve problems or seize opportunities (Cross, 2001). Design thinking gained mainstream following thanks

to the work of Kelley and Kelley at Stanford's d.school. Design thinking is housed under the broader theme of human-centered design which refers to the practice of solving problems by focusing on the human perspective at each phase of the process (IDEO.org, 2015). The hallmark of design thinking is its intentionally non-linear process centered around the following key phases:



*Fig. 11 The Design Thinking Process Image Credit: Stanford d.school*

At multiple points along the way, designers will loop back and repeat phases depending on the feedback from users. This means they may empathize, define the problem, begin ideating (brainstorming possible solutions) and realize they need to go back and empathize again. There may be smaller design cycles with-in the over all cycle. At each phase however, the focus on the work is on the person or people impacted by the problem or opportunity (d.school, 2009).

### **The Importance of Failure in the Problem Solving Process**

Throughout the design process, students will experience failure. Their initial solutions may not be well received by their users, their early prototypes may fail to solve the problem, they may find that their ideas are not feasible with the constraints of time or



funding. These opportunities to experience failure have a tremendous impact on high school students. Much of their education has been centered around avoiding failure, making finished products the first time and then moving on to the next thing. In design students will learn that failure provides the opportunity to make things better, to improve the solution and therefore the ultimate result. In an article for the New York Times, Sims writes that the habits of successful people regarding mistakes and failure include: feeling comfortable being wrong, trying wild ideas, being open to different experiences, playing with ideas without judging them, being willing to go against traditional ideas, persevering through difficulties (Sims, 2011). Fostering an ability to fail forward provides high school students with these skills.


### **Collaboration**

The third theme that is foundational to the formation of the STEAM Design Thinking and Innovation is the importance of collaboration. Our students experience most of their education in isolation. Group work is often used in classroom settings but is limited in both scope and duration. Collaboration over a significant period of time allows students to experience the satisfaction and challenge of working with others. The ability to collaborate is a skill that is in high demand at today's major organizations for-profit, non-profit, government, tech industries, healthcare, really every field that relies heavily on human capital requires individuals to work together. Offering opportunities for students to agree, disagree, seek consensus or proceed without it helps them develop collaboration skills and work effectively in future teams (Boaler, 2017). With the increase in online learning students are spending even more time in isolation and

the need to offer students the opportunity to develop collaboration skills in the classroom is essential. According to data from Project Tomorrow's annual Speak Up Survey, the percentage of high school students taking online courses nearly doubled in a single year. Further, 27 percent of all high school students took at least one class online according to the 2010 survey. This percentage is up from 14 percent as reported in the previous year (Nagel, 2010).

### **Benefits of Encouraging Collaboration Skills**

The Common Core State Standards for Literacy include the following standard:

**CCSS.ELA-Literacy.CCRA.SL.1**  Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

*Fig. 12 Collaboration Standard from the Common Core State Standards for Literacy*

Alber (2018) states that by the time they graduate, students need to be able to communicate in productive ways about a variety of topics with a diverse range of people while also being, “inclusive, articulate, and convincing of the importance and value of their individual ideas and stances” (Alber, 2018).

Humans are wired to work together. Driven by a need to connect, to share ideas and to understand what others are thinking we naturally work together. Yet, much of a student's educational experience is centered around the individual and the lonely pursuit of perfection. Middle school is a particular culprit in the isolation of our students. In middle school, students are seeking opportunities to connect with each other as part of their natural social and cognitive development process. However, with recent testing trends pushing students to isolate themselves for their own individual achievement, research shows that students of this age experience the majority of their school day in

isolation, working solo on individualized tasks instead of cooperative learning (Lieberman, 2013). Despite the increasing lack of collaboration in middle school, students can still develop and reap the benefits of collaboration. A study cited in the book, “Social: Why our brains are wired to connect” credits the single-variable manipulation of “belonging” as responsible for an increase in students GPAs in their first semester of college (Lieberman, 2013). Instead of turning off their social brains, mathematics classrooms should encourage students to learn in social contexts that foster collaboration.

Roschelle and Teasley (1995) define collaboration as, “a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem.” This is different from cooperation which is merely a division of labor among participating group members. Engaging students in opportunities collaborate rather than simply cooperate, offers them the chance to encounter conflicting ideas and manage misunderstandings. Collaborators use skills such as justification, assertions, elaborations, and counter-suggestions in an effort to make their meaning understood. In addition to voicing their own thoughts, collaborators engage in listening, questioning and other activities that build empathy as a means to understand their collaborators (Roschelle & Teasley, 1995). Cooperation opportunities abound in modern curriculum due to the incorporation of cooperation in the standards, but collaboration as defined by Roschelle and Teasley (1995) is more difficult to engineer. In designing the STEAM DTI course, there will be careful attention paid to the depth of collaboration offered by each project. Further, the instructors will be able to

mentor students teams as they develop necessary collaboration skills that are needed to resolve conflict, innovate together and manage large projects.

### **Collaboration: A 21st Century Job Skill**

The words of J. Tarnoff (2010), an entrepreneur and contributor to The Huffington Post, say much about the need for collaboration skills:

As an executive and entrepreneur sitting on both sides of the creative/technology fence, I need to hire technologists who know how to collaborate in teams, express themselves coherently, engagingly and persuasively, understand how to take and apply constructive criticism, I don't find these kids sitting alone at a lab table or buried in an algorithm. I find them taking art classes to understand how color and light really work (Tarnoff, 2010).

Tarnoff is not alone. In an address to shareholders, Jeff Bezos, Founder and CEO of Amazon, explained the company's hiring practices as culminating in an interview in which only three questions are considered, "will you admire this person?", "along what dimensions might this person be a superstar?", and "will this person raise the level of effectiveness for the group they're entering?" (Bezos, 1998). All of these statements indicate that recruiting trends in modern business are focused on building teams of employees who have skills to collaborate not just work in adjacent cubes. This new demand for collaboration skills may be a result of the new global economy.

The world economy is connected to such an extent as to require teams to be connected too, smarter, faster, more creative as a whole. To achieve this, individuals

need to learn how to be part of a team by recognizing both how they themselves think as well as how others on their team think.

Marakova and McArthur (2015) have investigated collaboration in modern businesses, and organizations. The authors suggest that recognizing collaborative traits may be beneficial to those wishing to strengthen their collaborative skills (Marakova & McArthur, 2015). The authors define four unique approaches to collaboration: Analytic, innovative, procedural and relational. They summarize each in the image at right. The

incorporation of this philosophy will be illuminated in the methods section.



Figure 13 Four Approaches to Collaboration

defined by Marakova and McArthur

In addition to the collaboration skills suggested by Marakova and McArthur (2015) as well as Weisman, Allen and Foster (2013) suggest that leadership skills are necessary in order to maximize the productivity of a team. The authors describe two different leadership styles, the multiplier and the diminisher. The diminisher sees themselves as the undisputed expert and intentionally or not, they engage in a way that belittles the ideas of others because they are only able to see the power of their own ideas. Multipliers on the other hand are able to recognize that the ideas of others may ultimately

be superior to their own, they seek a wide variety of voices offering solutions to a problem. They approach problem solving with a mindset that to get a great idea it takes a lot of ideas. Our education system is pumping out diminishers and is not producing multipliers. There is much emphasis on individual expertise and defending one's own work. Students need the opportunity to experience what it means to be a multiplier and to encourage the ideas of others in the pursuit of solutions that are innovative (Weisman, Allen & Foster, 2013).

### **Collaboration with Professionals and Community Members**

In addition to collaborating within the classroom, the STEAM DTI course will be offering students the opportunity to collaborate with professionals and community members. These community members will act as mentors, critical friends, brainstorming partners, networkers and more. Connecting students with professionals in STEM fields could make future career opportunities apparent and more appealing to students (Land, 2013). Engaging in collaboration with mentors who are experts or professionals in their own fields could affect the future education and career decisions of students (Keefe & Laidlaw, 2013).

### **Collaboration in Equitable Practices**

While a more in depth discussion of equity will occur in the following section, it is important to note that opportunities to engage in collaboration and develop related skills provide necessary benefits to minority students. A recent study shows that collaboration is an especially effective learning practice for African-American students. Through the course of the study, students of color engaged in learning activities that

promoted the development of social skills, leadership skills, and basic group skills. Students participated in these activities with in their math classes and over a sustained period of time. The results of the study showed that the collaborative activities had positive results on both achievement and attitude for students of color. The study's author concludes that students of color, "derive substantial social and academic benefit" from engaging in collaborative learning (Vaughan, 2010).

## **Equity**

### **Overview of the Issues of Equity in Mathematics Education**

An innovative mathematics curriculum offers more than an opportunity to do things differently. It also offers a potential solution to issues of equity in mathematics education is a topic of personal interest. In development of the STEAM Design Thinking and Innovation curriculum careful attention will be paid to issues and opportunities related to equity. Equity is a central focus at Evanston Township High School and is personally significant to the author.

### **The Role of Innovative Curriculum in Addressing Issues of Equity**

In the introduction to this chapter it was noted that 70% or more of U.S. jobs require the following qualities:

- collaborate with others
- investigate, define and solve problems using a variety of tools and resources
- communicate effectively
- design and manage work so that it continues to improve
- find, analyze and use information in a variety of forms and contexts

- develop new ideas and products (Darling-Hammond, 2012)

Currently, the United States Education system is not moving and changing rapidly enough to provide the type of education necessary for all of its students to develop these qualities. They are limited to the elite students as they have been for generations.

Current high school graduation rates have held steady at around 70% putting the U.S in the bottom half of industrialized nations. Despite the shake-up caused by the 1983 report, “A Nation at Risk”, the U.S. has continued lag behind much of the industrialized world. Even more disturbing is the gap between white students and students of color which continues to grow despite more education dollars, media attention and implementation of high stakes testing (Darling-Hammond, 2012).

We need to recognize the role that mathematics education has played in our culture of elitism. Mathematics programs favor those that can memorize and rapidly reproduce procedures. Labeling students as “gifted”, leads to a notion that there is a math gene and either a students has it or does not have it. In the United States, the math classes that students take from ninth grade on have the potential to determine the the opportunities available to the student for the rest of their lives. High school math programs should be doing all they can to ensure that all students have access to math courses that challenge students of all race and gender and provide access to high-level thinking skills. The vast majority of students who repeat algebra their ninth grade year and therefore are generally barred from taking AP calculus or AP statistics, are overwhelmingly Latinx or African American (Boaler, 2016). In an article which offers a hard look at the current state of math education, Geimer (2014) writes, “math education



is failing students because none of the founding minds of the major educational philosophies around which methodologies and curricula are designed knew how to most effectively and efficiently induce learning in the minds of students” (Geimer, 2014).

The search for innovative solutions to the equity concerns we have for our students must include conversations about dramatic curriculum change in mathematics. While it is noble to blindly push for more students to take AP Calculus, the data show that simply placing students of color and students identified as low socioeconomic status in the AP classrooms is not translating in to success for these students. Over 20 years the number of black students taking AP exams jumped from 2,768 to 113,000. However scoring distributions show that 25.4% of black students are receiving ratings of “qualified” or higher, compared to 63.1% of white students who received “qualified or better ratings” (JBHE Foundation Inc. 2008). We need to have honest, difficult conversations about where and when the divide between white students and students of color occurs and devise solutions that will prepare students of color and students who come from poverty to achieve in AP mathematics at rates comparable to their white peers. Until then however, we must not pretend that underachieving students of color will simply rise to the AP curriculum, that the computational procedural deficits experienced by many will simply vanish once they have access to the advanced curriculum. How might we offer students access to high level thinking courses that are an alternative to high-level computational-procedural courses? We must offer rigorous, authentic opportunities that will challenge all students to think creatively, develop

problem solving skills and achieve success in courses that can be considered honors level curriculum.

Means and Knapp (1991) highlight several equity concerns in their research. They point to studies that show that disadvantaged students (students of color or from low income families) often receive significantly less instructional time in higher order thinking skills and more time on rote or simple tasks. The authors charge that educators must reconsider the hierarchies of learning that assume skills are acquired in a linear fashion and instead shape educational experiences that meet students where they are and offer them opportunities to engage in these higher order thinking skills. It is often assumed, implicitly or explicitly, that these students lacked the skills to participate in this kind of thinking. This leads to classrooms in which students abilities are underestimated, challenging and intriguing opportunities are postponed and the resulting experience is anything but motivating and meaningful. This reality is visible in high school mathematics programs where students are barred from taking higher level thinking courses because they have not mastered the computational skills required in the early-levels of Algebra and Geometry. The authors suggest several key revisions to not only curriculum but of the very ethos of education. First, students should be engaged in solving complex, meaningful problems which have purpose and relevance. As the need for more basic skills arise within the context, educators should take advantage of the opportunity to “fill in” the necessary gaps. This top-down approach offers students a reason to care, and an opportunity to see a need for skills they may lack. The authors also suggest allowing students to connect their in-class work to their communities,

home-cultures and the global community. This provides relevance for the learning and gives the students the opportunity to create their own learning contexts (Means & Knapp, 1991).

In mathematics, throwing out the assumptions of skills hierarchies and offering rich problem solving opportunities to students who struggle with basic algebra means considering the nature of problem solving itself. Design Thinking provides a rigorous approach to problem solving that allows students to explore the nature of the problem and generate many possible solutions that can then be tested, reimaged and retested. This approach to problem solving allows students-regardless of computational skill to engage in the kind higher order thinking that other authors and researchers have called for. This reimagining requires educators to consider the expectations that are set for disadvantaged students (Boaler, 2017).

Providing an equitable education for students of color and low-income students is neither mysterious, nor unattainable. Research shows there are simple but powerful attitudes and curricula that are effective. For example, low-income youth perform at high levels when expectations placed on them are appropriately high. This means that simply expecting students to achieve at high levels can lead to higher achievement (Gorski, 2013). Further, individuals who believe they can make change are more likely to accomplish what they set out to do. They set their sights higher, persevere longer, try harder, are more likely to see failure as a learning opportunity rather than a roadblock (Bandura, 1994).

Haynes and Gebreyesus (1992) and Videro (2009) focused their research on the achievement of African American students in education settings. They discovered through their research that children raised in cooperative cultures such as those of African American families respond better to cooperative learning environments. Since much of a student's educational experience is individual, many African American students are learning in environments that do not match their preferred learning style. Mathematics classes that emphasize collaboration may provide African American students who have been raised in more social environments the opportunity to use their social upbringing as a learning tool (Haynes and Gebreyesus, 1992, Videro, 2009).

Rethinking the way disadvantaged students, students of color and students of low income families experience mathematics education has implications beyond test scores. There is evidence that current education systems are turning students off from the subject of mathematics to such a degree that merely the anxiety produced when contemplating mathematical tasks can induce physical pain (Lyons & Beilock, 2012). Further, students of color as well as other disadvantaged students experience a mathematics curriculum that leaves them disinterested (Mora, 2011). But there is evidence which suggests that incorporating cooperative learning, providing practical experiences and challenging activities leads to a greater level of retention for students in STEM fields and careers (Palmer, Maramba, & Dancy, 2011). The goals of the STEAM DTI curriculum are clearly set to encourage all students to develop higher order thinking skills in an innovative problem solving context. However, the focus on raising disadvantaged students will remain central to the design of the course.

## Summary

The preceding review of the literature examined the key themes that inspired the creation of the STEAM Design Thinking and Innovation course. First, the review examined interdisciplinary, or STEAM, education. Next, the review focused on the need for problem solving skills and the benefit of the Design Thinking process. Then, the review explained the need for collaboration in problem solving. Finally, the review explored issues of equity within mathematics education. Each theme represents an area of need within mathematics education and will be explored in order to answer the question, “*how can an interdisciplinary curriculum incorporate collaborative design-thinking to equip all students to tackle authentic, complex problems of critical relevance?*” This project will use the literature reviewed in this chapter to form the basis for the creation of the STEAM Design Thinking and Innovation curriculum. In the following chapter, the curriculum and methods will be described in detail. In the final chapter there will be a discussion of what is still needed and what the next rounds of user testing will look like.

## Chapter Three

### Curriculum Project Description

#### Overview

In the first chapter, the passion and purpose of this project was established. Chapter two summarized and synthesised the relevant literature supporting the creation of a new curriculum. Chapter three will outline the methods used to create the STEAM Design Thinking and Innovation curriculum. In asking, *“how might we design an interdisciplinary curriculum which incorporates collaborative and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?”*, the project seeks to generate a student-centered, problem-focused math curriculum which will center on collaboration and the integration of science, technology, engineering, art and mathematics (STEAM). Design Thinking provides the framework for the themes. This curriculum has the potential to offer unique opportunities to students of a wide range of mathematical abilities allowing traditionally high AND low achieving students to access this capstone level mathematics course. This focus on equity is central to the motivation behind the creation of this curriculum.

This chapter will outline the methods used to create the STEAM DTI curriculum. First, the participants and setting will be illuminated in order to provide context for the course. Then the curriculum overview will highlight the major projects and themes for the year. Next, a timeline for the completion of the project will be sketched out. There will also be a brief explanation of the importance of user testing and feedback to the

ongoing development of the course. Finally, a summary and preview of future development for the curriculum will be outlined.

## **Participants**

Evanston Township High School (ETHS) is located in Evanston, Illinois immediately bordering Chicago. While commonly thought to closely resemble the majority-white, wealthy Northwestern University community around which the city was founded, the population of Evanston is actually very diverse and more closely resembles the demographic of Chicago itself. With a mix of low-income families, immigrant families, middle class families and wealthy families, Evanston is no stranger to tensions and celebrations that result from such different lived experiences occurring in such close proximity. ETHS serves as the only public high school for the entire city and its 3,900 students reflect the diverse population of the city. The student body is 30% Black, 18% Hispanic, 6% Asian, 3 percent Other students of color and 44% white (Illinois State Board of Education, 2017). Historical context is also key to understanding ETHS and the setting in which the STEAM DTI course takes place. Barr (2014) writes about the current reality in Evanston. Although the city took efforts to desegregate the schools decades ago, Barr points to a “detrimental myth” of integration in Evanston. In addition to citing extensive evidence of actual segregation, found in the city archives and interviews with Evanstonians, Barr singles out the city’s own desegregation plan as partly to blame. The effort was aimed at all-black elementary schools and involved sending the students to elementary schools located in white neighborhoods. To this day, this requires busing the black children out of their neighborhoods and across the city while the

majority of white students can walk to their school. Not only has this created tensions it gave way to obvious markers of class difference. The result as Barr state as that, “the racial divide, far from being closed, was widened”.

Evanston Township High School speaks openly about the racial disparity in our city and in our school. Efforts to train staff and develop curriculum are always approaches through a lense of equity. It is with this equity lense that the STEAM DTI curriculum was developed. In addition to offering all students a rigorous problem solving course, STEAM DTI serves as an opportunity to elevate underserved, underprivileged students at the high school who have historically been denied access to higher level thinking courses due to a perceived lack of pre-requisite skills. This course is available to all senior students regardless of the math classes they have already completed. This means that the class will be filled with students who completed AP Calculus as well as students who struggled to finish Algebra 2. Recruitment efforts focus on populating the class with a demographic that matches the school profile.

### **Setting**

The course is offered as a double-period course (meaning two 43 minute class periods) in order to allow for deep engagement in projects, slow-thinking, field trips and meetings with mentors and community members. In addition to meeting in the classroom located at ETHS, the course will occasionally meet at Northwestern University’s Ford Engineering building as we partner with the Segal Design Institute. Further, students will be granted an unusual permission to leave the building in order to conduct interviews with community members and complete research that takes them out of the classroom.



The participants and setting are both unique and diverse. The student body and the school itself present immense challenges and wonderful opportunity for change and innovation in mathematics education. The ongoing development of the STEAM DTI curriculum centers around serving these diverse students at ETHS. The following section will highlight the major themes and projects of the STEAM DTI course.

### **Curriculum Overview**

#### **Paradigm**

The STEAM DTI curriculum aims to make five major shifts in how students experience classroom learning: the shift from product to process, the shift from consumption to production the shift from adult centered to student centered, the shift from competition to collaboration, the shift from risk averse to risk taking and finally the shift from single discipline thinking to interdisciplinary thinking.

Because this course was designed to offer an open ended experience in problem solving, there are several key focal points in the curriculum design paradigm. The course is conducted in two phases. Phase 1, first semester offers the students opportunities to engage in learning activities designed to foster creativity, innovation, collaboration, critical thinking, and generate a need for interdisciplinary teaming around problem solving. This phase of the course was designed with a more traditional approach that was modeled in part on the work of Wiggins and McTighe (2005) activities are designed with major goals and student learning objective in mind. Backwards design provides an excellent scaffolding process for students, it lays out- clearly, the expectations they are to meet. For the instructure, backwards design is ideal because it focuses the work of

planning on the desired skills students will acquire. In work and in life however, projects and outcomes are often open ended and the process can be just as important as the outcome. Therefore, much of the project work in the second semester, in phase two will focus on the process rather than the outcome. This open ended nature will offer students the opportunity to set their own objectives. Phase two second semester will offer students the chance to pull it all together as they work in teams to complete a capstone project this phase of the course is structured around the Design Thinking framework of Stanford's d.School (Stanford University d.school, 2009).

### **A Focus on Design Thinking**

While much of the first semester was structured using backwards design, the second semester follows framework of Design Thinking. Design Thinking is an approach to problem solving that encourages designers to first understand the who, then the what and finally the how. The phrase "design thinking" refers to thinking skills, mindsets, processes and practices which designers use to formulate new ideas they then use to solve problems or seize opportunities (Cross, 2001). Design thinking gained mainstream following thanks to the work of Kelley and Kelley at Stanford's d.school. Design thinking is housed under the broader theme of human-centered design which refers to the practice of solving problems by focusing on the human perspective at each phase of the process (IDEO.org, 2015). The hallmark of design thinking is its intentionally non-linear process centered around the following key phases:

### Stanford d.school Design Thinking Process

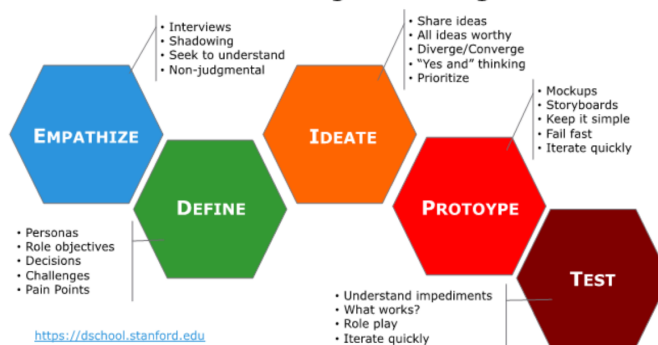


Fig. 14 The Design Thinking Process Image Credit: Stanford d.school

At multiple points along the way, designers will loop back and repeat phases depending on the feedback from users. This means they may empathize, define the problem, begin ideating (brainstorming possible solutions) and realize they need to go back and empathize again. There may be smaller design cycles with-in the over all cycle. At each phase however, the focus on the work is on the person or people impacted by the problem or opportunity (Stanford University d.school, 2009).

The overall development of this course was inspired by emancipatory action research as described by Mills (2018). The goal of emancipatory action research is to empower individuals to think outside the box, build knowledge, and free learners from the habits and dictates of tradition. (Mills, 2018 citing Kemmis, 1988). The design of this course was intended to disrupt the broader education system by testing new ways of engaging students in problem solving.

### A Focus on STEAM

Threaded throughout the course is an emphasis on the importance of interdisciplinary approaches to problem solving. Students examine the individual natures

of science, technology, engineering art and mathematics in order to understand that they are more alike than they are unlike in their approaches to problems solving. Further, students develop an understanding of benefits of creating teams of designers with diverse skill sets and backgrounds.

### **Semester 1: Laying the foundation and tapping creativity**

Examples of phase 1 curriculum that were developed include: a pre-assessment design challenge, flex of the day, soft-reading club, idea banking, curiosity conversations, brainstorming activities, process mapping, individual passion project, STEAM Inquiry and Research Poster project, and an Introduction to Design Thinking,

### **Make Something That Wasn't There Before**

The intent of this project is to create a need for collaboration and highlight the innovation process and demonstrate a need for a design process. MSTWTB project will act as a sort of pre assessment for the STEAM DTI Course. Student will experience discomfort with the lack of structure and guidelines as well as the intense collaboration with classmates they may not yet know. The following instructions to students:

- You must use every minute of your entire week
- The entire process must be collaborative
- You must document (with photos, words, video etc) what you do and how you do it.
- Keep your records in the form of a google slide presentation
- Your team must be prepared to describe, reflect and justify your idea. Why is this something that wasn't there before? How do you know?

It is expected that these instructions, because they are vague and open ended, may

cause frustration for student teams. It will be essential for the instructor to ease tensions and affirm students' efforts throughout the week. Student teams can create literally anything! Build something, make new art, create a movie, design an app, write a book, design a sketch comedy, record music whatever, as long as they can justify why it is something that wasn't there before, they have meet the requirement. Student teams will share their creations at the end of the 5 days. After the demonstrations, the following questions for reflection will help launch the course:

- What research did your team use? (likely, none)
- What was your inspiration?
- Was your creation a product? A service? A system? Or an environment? (leads to thinking about different kinds of prototypes)
- How did your team document your planning?
- Did you sketch your thinking?
- How did your team determine that your creation was relevant or needed?
- What question guided your efforts? (leads to the development of "How Might We..." questions)
- Was your creation designed with empathy? (probably won't understand this one)
- Was your design intuitive or intentional? (likely won't understand this question either)
- Was your team collaborative or cooperative? (Likely won't have a clear distinction yet about the difference between the two)
- Did your team engage in critique or criticism? (Again, unlikely that students will be able to articulate clear responses to this question)

## **Flex of the Day**

Adapted from an activity created for Northwestern University's Segal Design Institute, this ongoing component of the course is designed to engage the students as teachers. In teams, the students will be responsible for selecting a topic, activity and outcome for the first fifteen minutes of the class period. The team will lead the class through the activity and will lead the class in a reflection. A Flex of the Day might look and sound like this:

Student Team: Good afternoon, we are going to explore possible approaches to teaching body positivity. Using the Sharpies and post-it notes at your tables, write any questions you think a scientist, an artist, a mathematician, an engineer, or a technology expert would ask when approaching this topic. For this activity you will be following the "write-it, say-it, stick-it" method and then placing your post-it on the paper in front of you in the category that matches your question (STEAM or M). It is important to remember to say your idea to the group before you stick it and to be sure to listen to the ideas of the rest of your group too.

At this point, the student team would facilitate the 5 minute activity. Following the activity the team would ask the groups to share their ideas and would close the activity by reflecting on the importance of interdisciplinary approaches to problem solving as well as the importance of generating a lot of ideas as a way to get a single good idea.

### **Soft-Reading Book Club**

A twist on the book club, “Soft-Reading Club” as the name implies encourages students to “soft-read” material as a means of determining its worth to their individual research or needs. Students will select reading material (books, websites, journal articles, really anything!) and report to the group big takeaways from the reading so that others can choose to read it if it applies to them. Different from a deep analysis, the aim of this book club is to help students cast a wide net when searching for source material, to digest the essentials quickly, to develop a sense of when to read deeply and when to skim and to share information with others who might be interested.

### **Idea Banking**

Students will create digital and analog idea banks which they will use to gather ideas for their capstone project, ideas for possible Flex of the Day activities, fun, interesting and inspiring photos or articles. Anything they find useful to their work and life in general.

### **Curiosity Conversations**

This activity introduces students to the difficult process of cultivating human sources for research, developing empathy and user testing. In Curiosity Conversations, an activity based on the book “A Curious Mind”, by Grazer and Fishman (2015), we lower the stakes by requiring students to only seek an individual (non-family member, outside of the ETHS community) who they wish to learn more about. The students engage in face-to face or phone interviews with their selected person. The only goal of the interview is for students to learn the interviewee's story. Students craft open ended

questions and practice interviewing ahead of their scheduled interview. After the interviews, students reflect on their experience and follow up with their interviewee to thank them or ask follow-up questions.

### **Brainstorming Activities**

Throughout the first semester students will engage in brainstorming activities at various points in the first semester. Developing the ability to free-write and let ideas stream without prejudging their own ideas or the ideas of others will be a central focus of brainstorming. Writing ideas, as a team, on post-its in order to seed a project, as well as writing ideas individually in order to jumpstart a project are examples of written brainstorming work that will occur in the class.

In addition to brainstorming in writing, students will also brainstorm in drawing. This will occur as part of an early introduction to Design Thinking and will tap the resources of the high school by allowing the class to partner with a graphic design teacher. Students will learn basic skills for sketching ideas as a way of communicating. The goal is to help students expand their tool set for sharing their ideas with others. Students may struggle with this unit if they have not previously identified as, “artistic” and it will be important to develop a sense that perfection is not the goal rather, transmission of ideas.

The final type of brainstorming students will engage in is acting or body-storming. This will occur as part of the introduction to Design Thinking. In a two-day session with a local theater professional who works with industry giants such as McDonald’s and Google, the students will learn how to use acting (even terrible acting!)



to help empathize with the audience they are designing for. Role-playing allows for illumination of interactions, identifies areas where the designer lack understanding and prompts additional empathy research. Further, acting allows designers to illuminate their ideas for solutions they are developing by helping them see what they might look like in action.

### **Process Mapping**

The importance of interdisciplinary approaches to problem solving have been threaded throughout this course. To help illuminate the similarities between the STEAM disciplines, the class will engage in activities designed to highlight the individual approaches that each takes to solving problems. The class will engage in an activity that centers around the scientific method in order to expose the process scientists take when solving a problem. They will understand the Scientific Method as: question, research, hypothesis, testing/experimentation, results and sharing. Next, students will participate in a workshop in which they design an ideal city for a particular group or investors. They will use a method familiar to developers of technology called “scrum” in which they approach the problem in phases complete with report-outs, feedback, project and timeline updates. They will compare the scrum method to the waterfall method for problem solving. To explore the engineer’s approach to problem solving, students will engage in a building challenge that follows the design thinking process of empathy, define the problem, ideate, iterate. For art, students will be commissioned to create a visual messaging campaign for a local elementary school. The teams will need to brainstorm messages and ideas, test out some early concepts, implement their idea as a sidewalk

chalk drawing at the elementary school and document how their audience interacts with their art. Finally, to explore mathematics as a problem solving process, students will learn to solve a Rubik's cube. They will see the approach to solving the cube as a series of steps including testing, iteration, forming a solution and generalizing their solution to larger cubes. After experiencing the processes of each discipline, students will then be able to not only describe the problem solving approach each discipline uses but also will be able to identify and describe the extent to which they see overlap or similarity in the process. By articulating this, students will demonstrate a deeper understanding of how problem solving works in general as well as in specific disciplines.

### **Individual Passion Project**

This is one of very few individual assignments of the course. The individual passion project challenges students to perform a “deep-dive” into an area of interest for them. The project follows four phases. First, students will select an area of interest. There are no restrictions other than requiring students to select a topic that is robust enough for the scope of the project. Students will justify their choice and identify the primary field of study by stating which STEAM discipline they believe most broadly encompasses their topic. Next, students will investigate their topic to learn how the STEAM disciplines interact and play key roles in their topic of choice. For this phase, students will first brainstorm an extensive list of questions that will guide their investigation. After generating questions, students will not only conduct internet and reading based research but they will also reach out to professionals in the industry that houses their topic. After their investigation they will analyze their research through a

series of questions designed to help them illuminate the roles of science, technology, engineering, art and math with in their topic. From there they will extrapolate by suggesting and justifying suggestions for where more could be done to increase interdisciplinary problem solving with in their selected topic. Students will share their process and results in presentations to the group that are structured like Tedtalks. Student will focus create their presentations around four guideline as suggested by Anderson (2016) in a Ted talk titled, Ted's Secret to Great Public Speaking.

1. Focus on one major idea
2. Give your listeners a reason to care
3. Build your idea piece by piece out of concepts your audience understands
4. Make your idea worth sharing

The goal of this process is to allow students to develop research skills, interview skills project management skills as well as public speaking skills. Further, the goal of this project is to provide students additional opportunity to explore the need for interdisciplinary problem solving.

### **STEAM Inquiry and Research Poster Project**

In teams of two to four, students will examine a complex problem that requires multiple problem-solving approaches. They will explore the problem through the lens of each of the 5 unique STEAM disciplines, then synthesize multiple approaches to a narrow sub-problem. Ultimately, students will research current approaches and prepare a research poster that assesses multiple possible solutions. Themes will rotate throughout the life of the course and will include: climate change, urban city planning,

sustainability, local health concerns, emergency response and other topics of interest with robust interconnected problems needing solutions. The class will partner with an expert in science communication from Northwestern University who will help assist them in the design of their posters.

### **Interviews with experts**

Interviews with experts will be integrated into the first semester of the STEAM DTI course. For example, we will speak with a project manager who works at Path, one of the largest organization addressing issues related to global health. Students will learn how this team leader assembles and manages teams of scientists, communications experts, technicians, and local representatives. Students will ask questions about how the teams deal with communication, collaboration, failure and problem solving in general.

The students will also participate in an event called “Practitioner Speed-Interviews”. Representatives from each of the STEAM disciplines will gather and the students will have 10 minutes to interview each of them about their work, their problem solving process, their approaches to dealing with failure and more.

Students will also have the opportunity to engage with a local design firm called Greater Good Studios. This Chicago based firm focus on social impact design and consulting. Students will tour the design studio and meet with the designers to learn about what design looks like in a professional setting.

Students will also meet with a panel of recent college graduates who are engaged in the field of design. The panel will allow the students to inquire about possible careers or educational paths in design.

## **Introduction to Design Thinking**

After concluding the previous activities designed to establish a mindset, foster creative confidence, define innovation and generate a need for interdisciplinary problem solving, students will be formally introduced to Design Thinking as a problem solving approach. While there is no one single design philosophy which must be taught, Design Thinking, as defined by Kelly and Kelly (2009) at the Stanford d.school provides a structure that allows students to engage in design through a series of phases. First, students will be introduced to the process through a one-day activity called, “Re-design your partner’s gift giving experience”. This will allow them to follow a fairly scripted path with a low-stakes topic in order to illuminate the Design Thinking process (d.school, 2009).

Then, students will engage in a classic Design Thinking activity called, “Re-design your partner’s wallet” (d.school, 2009). This activity will be more open-ended and will require multiple days for students to interview their partners in order to truly understand their needs. Then students will ideate, design an early prototype, offer it to their partner for feedback and then redesign their product.

## **ETHS challenge**

The first two design challenges are intended to be small scale introductions to the process and purpose of each phase of Design Thinking. The following challenges offer students the chance to scale up their experiences. First, student teams will receive a design challenged that centers around the ETHS community. An example would be, “Explore the marketing and usage of #wildkitway” (#wildkitway is used by ETHS

communications staff but has different meanings around the school and various organizations within the school have expressed frustration at the nebulous nature of it) and design a solution that would increase students usage of and understanding of #wildkitway. Another example would be, “Design a way to improve health here at ETHS”. This design challenge would cover a few weeks and would allow the students to begin to work with slightly less structure while still remaining in the school community.

### **STEM Challenges**

After completing the “in-house” design challenge, it will be time for students to expand to a broader community focus. In partnership with the Illinois Science and Technology Institute, students will spend eight weeks (or more) tackling big design challenges for real organizations such as the following:

From Takeda Pharmaceuticals:

“Improve a challenge encountered by a patient in their treatment journey in one of Takeda's therapeutic areas. Research and explore to better understand symptoms, diagnosis, treatment options, and the quality of life that patients face.” (ISTI, 2017)

From Uptake data firm:

“Uptake is seeking your perspective about what they can learn about students, from students. Your Challenge is to use Student Union as a jumping off point to develop your own data and conclusions about what factors contribute to, and might help to predict future student success.” (ISTI, 2017).

From the City of Evanston:

“The City of Evanston is looking to you as citizens, and the next generation of innovators, to help recommend new approaches in emergency management. Ordinary citizens like you are often the new first responders, often equipped with a communication device that allows you to pinpoint the location, take pictures or video, and spread an alert via social media. Consider the potential power and responsibility that engaged citizens across our diverse community hold in the areas of risk assessment, preparation, response, mitigation and recovery. The City hopes to learn from your insights and experiences as you bring fresh ideas for innovation in emergency management.”

Students will conduct research by looking at data as well as interviewing users in their defined audience. They will contact professionals and experts within their chosen field of study. Students will be charged with identifying a specific area of focus in order to define the problem. Students will meet with mentors from their partnering organization as they ideate and conduct research. Student teams will then focus on crafting a “how might we...” statement to guide their ideation phase. The “how might we...” is important because “how” implies that the team believes a solution exists, “might” communicates that there is room for flexibility, direction change and failure along the way and “we” speaks to the collaborative nature of problem solving and the need for multiple perspectives (Robinson and Cantor Aye, 2018). Then students will generate possible solutions, interview stakeholders for feedback, develop prototypes and complete several rounds of testing before reporting their findings and plans for future research.

Prototyping will take on a more significant role in this project. Students will engage in a week-long prototyping crash course. During this week they will be introduced to the four types of prototypes; a product, a system, an environment and a service. While many students think of design and prototyping as building a “thing”, a goal of STEAM DTI will be to expand that thinking to include other types of solutions such as a process, an environment or a system. A process could mean a new way to share information in a hospital to ensure that patients get timely treatments. An environmental solution refers to designing or redesigning a space. For example, teams may decide to create a women and girls reading room at the local YWCA. Designing a service could look like the creation of a reverse-delivery service for Amazon to pick up the boxes used to deliver its products.

While they are unlikely to see their process through to a fully marketable solution, they will be able to more fully immerse themselves in the process of development than in previous activities. This project will culminate in a demonstration and showcase attended by representatives and mentors from the organizations that offered the design challenges. Students will report their findings, demonstrate prototypes and discuss plans for future research and testing.

## **Semester 2: Pulling it all together in the capstone project**

The course culminates with a second semester capstone project. For this, students will assemble themselves into teams based on their own areas of interest. Several design challenges will be made available to the students but teams may also identify their own area of need. After brainstorming and settling on one or two broad topics, the students



will participate in a Think Tank with local community members who will be able to connect them with valuable resources, assist them with additional brainstorming, and offer support or critique. The Think Tank is designed to help the students flare-meaning widen their search but also focus-narrow in on a single area to investigate. Following the Think Tank, the teams will focus in on a single area they wish to investigate for their capstone project. The teams will produce proposals stating the topic area, listing possible resources, and a plan for how they will work to define a problem for a particular user group.

After submitting their proposal, student teams will delve into a lengthy research phase lasting approximately five weeks. During this phase they will read, conduct interviews and work to develop empathy with stakeholders (audience/user group) that connect to their topic of choice. They will work to uncover “pain points” or opportunities for innovation. Student teams will design and participate in an activity which allows them to experience their user’s point of view first hand. For example, student researching food access might request to accompany local residents on their trips to local stores. Students would document how the user traveled to and from the store, what their experience at the store entailed and how they felt about shopping for food in general. At the end of the research phase, the team will have identified a particular user group and defined the problem they are going to focus on in the coming months.

After defining the problem, teams may need to conduct additional research and empathy building exercises in order to more deeply understand the problem and the user. Teams will also begin ideation. In this phase, teams will cast a wide net when

brainstorming, they will seek to draw out even the wildest ideas that are tucked into their teammates heads. They will take these ideas and group them around themes or strands. They will analyse the ideas using a SWOT analysis. SWOT stands for strengths, weaknesses, threats and opportunities. In addition to their SWOT analysis, they will take their ideas to their users and solicit additional feedback, searching for emotional reactions both positive and negative as well as concrete suggestions.

Once they have narrowed to one or two key solutions, they will begin prototyping and testing. At this point, student teams may have settled on one of four types of solutions; a product, a service, an environment or a system, they will justify their solution by connecting it to their research. Then they will develop prototypes to test with their users. They may prototype a single solution or components of the solution. For each prototype, the team will draft one or two questions which they hope to have answered by their prototype. For example, a team designing a coloring book for children might want to ask, “to what extent do children use the coloring book independently and to what extent do they interact with an adult?” After each prototyping phase, the teams will gather and analyse their data and either redesign the component or focus on another aspect of the solution.

The entire process is intentionally non-linear, allowing teams to loop back to research and empathy as needed or continue to ideate as the encounter failure. High school students are likely to struggle with the open ended, non-linear nature of this process because most are used to clear paths laid before them complete with rubrics and checklists. These will not exist for this project and so conflict between teams may

emerge as the teams struggle to chart a path. It is also because of this open ended nature that the outcome will be less significant than the process itself. Because it is the intent of the project to allow students to tackle juicy and actionable problems and opportunities for their designs, it is assumed that a fully developed solution would likely take months, years, even decades. It is possible that the students would be able to hand over their work to a local entity but it is also possible that the project simply fades as the students leave high school. Therefore, careful consideration will be needed as the students are encouraged to take big risks and focus on the process and the skills they are developing rather than focus on churning out a “finished product”.

After several rounds of user testing, the student teams will prepare demonstrations. The demonstrations will include a detailed story telling of their journey to this point, it will also involve audience participation as the student teams pass around their product, display a model of their environment, or act out a new system or service. The audience for this demonstration will include all community members who mentored the students through this project, parents of the students, school administrators and anyone who joined the class along the way. Below is a timeline of the capstone project process:

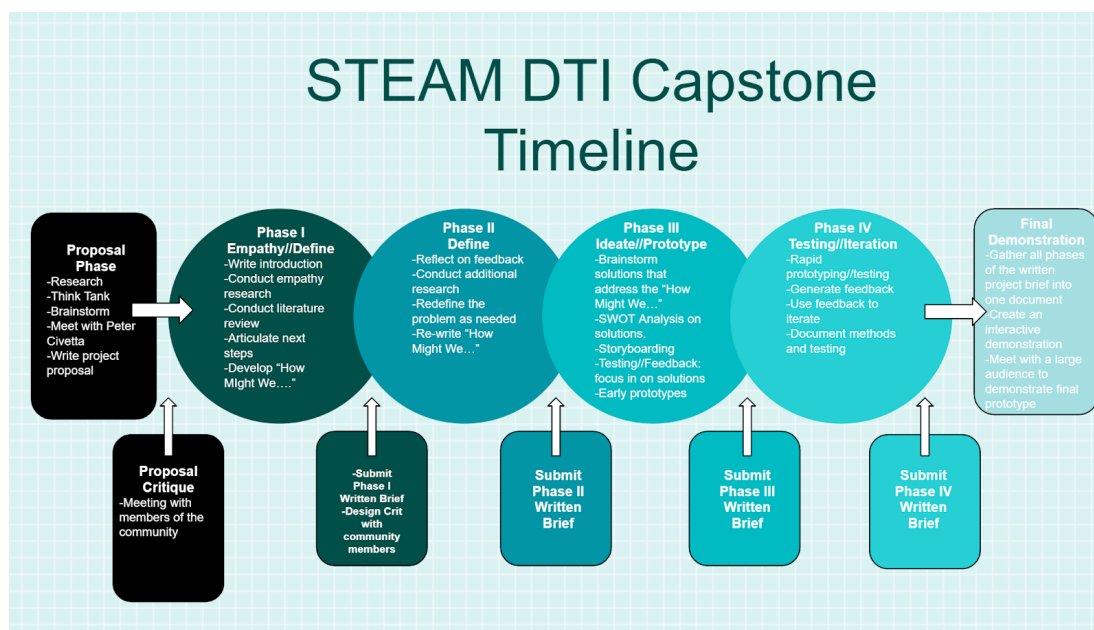


Fig. 15 Second Semester Timeline for STEAM DTI Capstone. Copyright Klyn 2018

While the first semester projects and themes are designed to introduce students to the paradigm of the course and build skills, the second semester project is designed as an opportunity to let them shine! Students will take their skills and knowledge, acquired from over twelve years in education system and work together to do something on a much grader scale than they have been able to do before. The methods described in the preceding section each support this huge goal. Because it is still a new course, these methods will require testing and analysis of feedback, the next section briefly describes the important role user feedback will play in the continued development of the course.

### **The Importance of Testing, User Feedback and Iteration**

A fundamental principle of design is incorporating user feedback into the continued improvement of the product, service or environment. As indicated in the timeline, development of this curriculum will make full use of this tool. Throughout the course, students will be given the opportunity to offer feedback and suggestions which

will be incorporated into the ongoing implementation of the course itself. Innovations will occur on the spot not just incorporated into future versions of the course. After each project is completed or each phase has ended, ideas for how to innovate or iterate within the paradigm of the course will be analyzed and considered for further testing. While the development of STEAM DTI will be an ongoing and eternal process, the following timeline for implementation will lay out the path to completing the first formalized curriculum for STEAM DTI. Future versions will undoubtedly follow!

### **Timeline for curriculum development and continued testing**

Below is an anticipated timeline for development of this curriculum:

Current:

The STEAM DTI course is in its pilot year (school year 2017-2018). Several of the ideas listed above have been or are being implemented with nine current students.

Summer 2018:

The STEAM DTI Summer Research and Design program will be held at Northwestern University. This is a three week condensed version of the course intended to serve as a lab for testing ideas further. Students will participate in smaller scale versions of many of the activities listed above. The feedback and experience will be used to guide further development of the course.

- The ideas listed above will be refined for this second iteration and are available as appendices after completion of chapter four.

- Iteration and improvements to the projects are immediate and ongoing based on student feedback.

- Reflection on the second round of testing the course will be ongoing.
- Questions for future development of the course including changes to the projects, inclusion of more art and more STEM, deepening connections to the community and focusing on long-term sustainability are formed and offered for discussion with stakeholders.

Summer 2018:

- The curriculum is formalized and “packaged” for the second year of the course, with 28 students.

Ongoing and open ended questions:

- Discussion of how to scale up or share out is ongoing.
- Planning for how to measure student growth in future courses begins.
- A community advisory board is formed.

### **Summary**

This chapter offers the outline for a solution to the research question posed in this project, *“how might we design an interdisciplinary curriculum which incorporates collaborative and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?”* Introducing students to interdisciplinary problem solving, fostering creativity, engaging them with professionals and community members and introducing them to Design Thinking are the goals for the first semester of the course. The major goal of the second semester is the completion of a capstone project designed to showcase the students deep knowledge bases, wide ranging skill sets and highlight their learning process throughout the course of the year. This curriculum was

designed not only to offer rich, authentic problem solving opportunities to high school students, but also as a possible solution to the achievement gap by encouraging students of color who might otherwise be barred from enrolling in high-level thinking courses due to the hierarchies of high school mathematics.

The following chapter will offer reflections on the development of the curriculum and a detailed analysis of the strengths, weaknesses, threats and opportunities will be presented. In addition, the following chapter will highlight future goals for the course and its continued development. Finally, the following chapter will offer a detailed list of open questions which will require ongoing investigation by myself, the student users and perhaps the broader educational research community.

## Chapter 4:

### Results

#### Overview

What started with a desire to change the way students feel about math class has transformed into a research question. *How might we design an interdisciplinary curriculum which incorporates collaboration and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?* The search for an answer has culminated in the creation of a new mathematics course to be offered at Evanston Township High School. STEAM Design Thinking and Innovation (STEAM DTI) incorporates science, technology, engineering, art and mathematics into problem solving experiences that foster critical thinking, collaboration across networks, leading by influence, agility, adaptability, initiative, entrepreneurship, oral and written communication, accessing and analyzing information, curiosity, imagination and resourcefulness. This curriculum seeks to make six major shifts in student learning; from product to process, from consumption to production, from adult-centered to student-centered, from competition to collaboration, from risk averse to risk taking and from single discipline thinking to interdisciplinary thinking. Throughout its development, the STEAM DTI curriculum has been viewed through a lense of equity which seeks to remove barriers to higher-level thinking for traditionally disadvantaged student groups. Inspired by the work of disruptive educators and Stanford University's d.school, the curriculum will be available to high schools that wish to offer their students authentic problem solving experiences. In this, the concluding chapter, I will first



describe the key takeaways from the process of developing this curriculum. Next, I will revisit the literature review to highlight the most influential resources. A discussion of the implications of the STEAM DTI curriculum will focus on both the implications for mathematics education policy at large, as well as for students who take the course. I will offer my thoughts on how the STEAM DTI curriculum contributes to the broader conversation, highlight the limitations of the curriculum in its current form, and open questions that will be addressed in its continued development. Suggestions for future research and development and a description of next steps for implementation will be followed by plans for sharing results and scaling up. Throughout this chapter the reader will notice that I feel both a great sense of accomplishment as well as a deep motivation to continue to answer the stated research question. This is because, as a result of the successes that have come from the efforts to develop the STEAM DTI curriculum, there are now even more questions to answer and new things to try. This is the Design Thinking way.

### **Key Takeaways**

When I began my journey to complete this project, I was excited about the opportunity to do something new, I was nervous about sticking my neck out in an effort to disrupt and I was wary about the feedback I would receive. I have learned a great deal through seeking answers to countless questions and I am absolutely certain that I have just as many questions now as I did when I started! The most significant takeaways for me all relate to the systems, structures and status quos of education itself.

First, I have learned that there is an enormous amount of discussion and inquiry into the need for flexible, adaptive curricula for students, but the conversation is almost exclusive to higher education and the professional world. Books, articles, and curricula are being developed with a focus on interdisciplinary learning and problem solving at the higher education level, but little of the conversation is occurring in regards to K-12 education. While conducting my literature review, most of the literature I reviewed and nearly all of the resources I used to develop the STEAM DTI curriculum were created for higher education or business. It has left me with a desire to determine if and to what extent our education system is outdated, redundant, or insufficient.

Despite the lack of established conversation and resources around the type of curriculum I am developing, I was surprised to find such a high level of enthusiasm for the creation of a course of this nature. In conversations with community members, university professors, parents of students, fellow teachers and administrators, the feedback was always positive and I received absolutely no push back. I thought I would meet resistance because the curriculum I was hoping to develop was intended to disrupt traditional education models, yet the most common sentiment that was offered was, “Gee I wish there was a class like that when I was in high school!”

While I did not experience push back from individuals, I was surprised by how hard the structures and practices of education seemed to push back. I felt a great deal of discord between the ideas presented in the work of Wiggins and McTighe and my development of this curriculum. Considered the “gold-standard” of education, Understanding by Design promotes establishing a clear end goal or outcome for students.

I found this to be in conflict with a core component of the curriculum I was designing, the open-ended, student-driven journey which reveals needed skills that I might not have anticipated. Wiggins and McTighe's model promotes control and predictable assessment while my intention with this curriculum was to release a portion of that control to the students and the process, thus limiting the predictability of the outcomes.

In addition to finding a balance between industry-standard best-practice and disruptive innovation, I discovered new truths about designing and implementing innovative curricula. I learned that I am fortunate to have a significant amount resources available to me that are unusual. I have been granted an enormous amount of time, money and support from my administration to take on this challenge. With many of the traditional constraints lifted I will be supported in ongoing experimentation with this course.

I have been given the freedom to experiment and have been released from traditional curriculum constraints, with this, there is an expectation that students will develop skill sets beyond the narrow sets of mathematics standards. Because of this new pursuit, I have discovered how truly difficult it is to assess soft skills such as collaboration, creativity, innovation and resilience. Tracking growth and achievement in quantifiable data driven ways is desirable in today's education environment. As a math teacher, I am well trained in grading more traditional math assessments but attempting to convey the extent to which a student has become a better collaborator has been an ongoing challenge for me. Further, the open ended and student driven nature of the projects and units of this course also present a challenge for assessment. I have begun to

research methods of measuring student development and creating assessment which will be described in more detail in the discussion about next steps.

### **Revisiting the Literature**

Throughout the development of the STEAM DTI curriculum I have found myself re-reading several texts which served as touchstones for the course. *Creative Confidence* (Kelley & Kelley, 2015) and *The Innovator's Mindset* (Couros, 2015) both shaped the personality of each assignment and will influence the way I approach facilitating the activities and projects. I regularly connected the intent of the lesson to the ideas suggested in each of these texts.

As the development of the curriculum unfolded, I found myself revisiting the work of Wagner (2012 and 2014). Wagner's writings conveyed a deep sense of urgency for opening educational experiences for students which promote creativity, collaboration, innovation and resilience. As I was considering how to craft the lessons and activities, I could hear the words of Wagner in my mind. Each curriculum component connects to a key theme of Wagner's.

For the development of the individual materials, I relied heavily on the materials from Stanford's d.school (2009) as well as the pedagogical philosophy of *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching* (Boaler, 2016). The d.school frameworks provided many resources for activities and supplementary readings and offered me a new way of thinking about problem solving. The work of Boaler provided an equity lens for me as I considered how to structure the activities to ensure multiple entry points for students, opportunities for

students to observe their own growth and access to higher level thinking experiences for students who may not have traditionally desired skill sets.

As I was working on the curriculum I continued to discover new sources that support the development of curriculums of this type. I was overwhelmed by the desire to synthesise and incorporate all of the available literature as well as emerging research. In the end, I have accepted the fact that this is a new line of inquiry for education and I will be continuing to acquire new resources as I make future revisions of this curriculum.

Although there continues to be a flood of new literature related to my topic, it seems to be focused on higher education. I have realized through this process that there is only a narrow body of work that focuses on curriculum resources for Design Thinking and related experiences for high school students. There are resources for creating STEAM based lessons which combine traditional disciplines, there is a wide range of literature discussing the need for authentic assessment, but I have encountered only a few sources that dive into authentic problem solving and open ended experiences in the classroom.

### **Implications**

As previously mentioned, I have not encountered many sources which show the impact or results of implementing a curriculum like STEAM DTI. The implication here is that this work could help shape the conversation about what should be included in mathematics curriculum or what opportunities should be made available to high school students. This project offers the opportunity to design, gather feedback iterate and continue to test new ways for students to develop problem solving skills in a high school

math classroom. The STEAM DTI curriculum and its implementation could reveal a new mechanism for meeting the needs of today's students. The opportunity to add to the conversation about valuable curriculum for students is exciting. If success can be demonstrated, and the results can shared and expanded, perhaps this could impact math education standards. I would like to see my work contribute to the policy discussion regarding required standards for mathematics education. I believe standards which include broader problem solving skills like collaboration, defining problem space, and design in general would benefit our students. I would like to see the math standards expanded to require students to have hands-on and real-world problems to tackle, problems that don't wrap themselves up nicely in a class period.

### **Contributions to the profession**

In addition to helping shape future mathematics standards, this curriculum project offers additional contributions to the educational profession. First, this project adds to the conversation about authentic learning by posing several questions. What is authentic learning? What skills do students develop when given open-ended problem-solving opportunities? Finally, what is the benefit to students to experience on-going, real-world problems that can not be quickly analyzed and solved? The second key contribution of this project is the opportunity for disruptive innovation. Because change is uncomfortable, slow and requires both physical supports like time and money but also a unified will to try, this experimental curriculum contributes to the profession by acting as a disruptive innovator. Disruptive innovation, can be described as making change from within. By using existing systems and norms but pushing the boundaries or adding new

systems and norms, significant change can occur (Christensen, Raynor & McDonald, 2015). In education this can be summarized as creating change by pushing on existing frameworks. Rather than completely blowing up the status-quos, the STEAM DTI curriculum embraces traditional frameworks and standards while trying to push the boundaries and create space for new methodologies.

### **Limitations and open questions**

In part because the STEAM DTI curriculum pushes on existing norms, there are limitations. Further, because this curriculum is new and untested, there are many open questions. Limitations and open questions will both be explored throughout the continued development of this curriculum. Testing and iteration as well as student feedback and substantial reflection on my own part will ensure that the curriculum is constantly evolving. First, a significant limitation of this curriculum is its ability to be adapted to large class sizes. The activities in their current form are best suited to groups of twelve to sixteen. This could be a significant limitation to implementing in classrooms of twenty-eight students (or more).

Assessment is another area of limitation. Because the curriculum is new and existing frameworks for assessment do not yet exist, assessing students these first years will be insufficient. Assessing will be awkward at first and will require additional innovation. Through experience and continued reflection, as well as drawing on current curriculum models such as the International Baccalaureate Design curriculum and tools developed by Northwestern University and Stanford University, I plan to develop and document ways to assess students taking STEAM DTI.

A major limitation to this project is its reliance on funding and support. It must be acknowledged that many willing teachers would not be able to take the leap I have been able to take because they do not have access to funding or lack the administrative support to take such wild leaps of faith!

In addition to exploring limitations, I still have curriculum items that are in development or need additional collaboration or resources. There are several activities and units such as the sketching unit and the ISTI workshop that are currently “brain-children” of collaborations between myself and other stakeholders. The sketching unit is planned for an upcoming year and will be developed collaboratively with a graphic design teacher at the school where this curriculum will be implemented. Like the sketching unit, it is my intent to constantly explore partnerships within the school. Future explorations include possible cooperative teaching with English or Art instructors and offering the class as a dual credit Math and Art/English. This is the desire of the administration and will be implemented as part of a five year plan for the course. Also under construction are experiences created in collaboration with the Illinois Institute of Science and Technology. The partnership has just been established and development of the student experience will take place in the fall of 2018.

### **Suggestions for future research and development**

As mentioned previously, a limitation of the curriculum lies in assessing student growth and predicting project outcomes. Future research will focus on how to determine which skills are most valuable to assess and the most effective ways to assess those skills. The efforts could focus both on how the instructors determine growth and also how



students can monitor their own growth and self-assess. Additionally, as students complete open-ended projects, patterns will emerge that will make the student experience more predictable.

Understanding the impact the curriculum has on students' future experiences such as college and career would also be valuable research. I would like to develop methods to track students through college and into their adult lives to see if they developed skills that proved to be worthwhile. Finding a way to compare the experiences of students who took STEAM DTI to the experiences of students who did not take STEAM DTI would be valuable information in determining what activities and experiences were most valuable to students.

Finally, exploring the impact of the STEAM DTI curriculum on traditionally disadvantaged students will be important. One of the aims of the course is to provide students who would be traditionally barred from engaging in higher-level-thinking-skills based courses the opportunity to tackle rich problems with complex solutions. Assessing the impact on this particular group of students is an important component of my own focus on issues of equity in education.

### **Next steps**

I will be teaching this course with twenty-eight students for the 2018-2019 school year. This is both exciting and terrifying because there are so many unknowns. Throughout the year I will be collecting feedback from students and making changes to the curriculum after the activities have been completed as well as innovating on the fly! This attention to user testing and student feedback will shape the course of instruction.

Because I have the flexibility and support of the administration, I will be able to extend the timeline on projects if the students would benefit from additional time or scrap plans altogether if students might not benefit from them.

Next steps will include the exploration of new partnerships with local organizations which would offer mentorships, design challenges, connections to local professionals etc. I would like to create an advisory board which would bring together community members who would act as promoters for the course as well as help us secure resources that might enhance the long-term projects.

### **Sharing results and scaling up**

The next steps for the STEAM DTI course also include plans to share results and solicit feedback from the broader education community. Continuing to develop this curriculum in isolation will lead to stagnation if the only ideas are coming from the small team at Evanston Township High School. It is my intent to bring the ideas behind STEAM DTI to professional educator gatherings such as the National Council of Teachers of Mathematics as well the International Technology and Engineering Association. The purpose of bringing the curriculum would be to offer an opportunity to design experiences that educators could take back to their classrooms. I would like to facilitate design challenges in which educators engage in activities from this curriculum or bring their own classroom activities and redesign them to offer a more open-ended innovation driven experience for students. I would hope to gain insight and feedback about the use of design thinking in the classroom. Rather than present this great new

thing, I would aim to help teachers (and myself) develop new great things keeping with the STEAM DTI ethos.

### Summary

In conclusion, the search for a way to answer the question, “*How might we design an interdisciplinary curriculum which incorporates collaboration and design-thinking to equip all students to tackle authentic, complex problems of critical relevance?*” has lead to the creation and ongoing development of the STEAM DTI curriculum. I have learned that there is great enthusiasm for a curriculum like STEAM DTI but that existing structures and status-quos provide resistance. I have learned that the success of this curriculum depends on the support of innovation-focused professionals and community members. I have discovered new areas for research including assessment of so-called soft skills.

In addition to the opportunities for future research, I am excited about the next steps for the course which include implementation and continued user testing as well as connecting with the broader education and design communities for feedback and sharing out. It is my hope that I can continue to iterate within the ethos of the STEAM DTI course. I can imagine myself in five, ten or twenty years tackling the newest problems facing both local and global communities with a group of passionate high school students who believe they can change their world, regardless of how well they can solve an equation.

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## APPENDIX A: Curriculum Overview

**STEAM DTI 2018 // Curriculum Overview****Unit 1: Introduction to the course paradigm.**

*In this first unit, students will be introduced to the course paradigm. Students will participate in a design challenge-pre-assessment. Students will begin to deconstruct the problem-solving approach of each of the 5 STEAM disciplines separately by interviewing professionals and exploring community resources. Through team building activities and personal assessments, they will explore their learning style, cognitive and affective strengths/challenges, and reflect on intergroup dynamics. Students will explore and find value in creative pursuits.*

**Week One:**

[Classroom Profile](#): Students will make a profile with a picture and 6 words to be hung in the classroom for the year.

[Make Something that Wasn't There Before](#): Teams of four will work together with very few guidelines other than to “make something that wasn't there before” Teams will document their process and share their final product after 5 class periods.

[Flex of the Day](#): Instructors will lead the class in 4 different Flex of the Day Activities. Then students will form small teams (2-4) and sign up for opportunities to [plan and lead](#) flex of the days for the class.

[Idea Bank](#): Students will create and share an idea bank that will be used throughout the year.

[Intro to the Course](#): After the student teams have been working for some time, we will discuss the expectations of the course in general

Week one Team Building: [Letter of commitment](#) and team charter

Students will each pen a letter committing to the hard work and collaboration needed to be successful in the upcoming year. The whole class will also sign a team charter created this week.

**Week Two:**[Personal Profile](#)

Students will complete a short survey related to the STEAM course. Students will create a google folder [portfolio containing three items](#): A complete list of their areas of expertise, a complete list of the current areas of interest (including hobbies, studies and activism) and

a pdf of a completed personality survey.

Field Trip to NU:

The STEAM DTI course will travel to Northwestern University to visit the Ford Engineering building. Pam Daniels and David Gatchell will give us a tour and introduce the students to the world of making and problem solving at NU!

[Introduction to Curiosity Conversations \(Unit 2\)](#)

[Introduction to Book Club \(Unit 3\)](#)

[Practitioner Speed Interviews](#)

Students will meet with experts in each of the STEAM disciplines. Conversations will last approximately 5 minutes each. Students will ask questions about the experts work, their approach to collaboration and their response to failure. This activity is designed to help launch the curiosity conversation as well as introduce the students to the notion of interviewing experts.

Week two Team Building (as flex of the day activities led by instructors if needed, otherwise saved for later):

[Broken Circles](#)

[Experiencing Discomfort](#)

[Building Shapes](#)

## **Unit 2: Creativity through Multiple Lenses: The Local Impact of Global Climate Change**

*In this unit, students will examine a complex problem that requires creativity through multiple problem-solving approaches. They will explore the problem through the lens of each of the 5 unique STEAM disciplines, then synthesize multiple approaches to a narrow sub-problem. Ultimately, students will research current approaches and prepare a Poster Presentation that assesses multiple possible solutions. Students will explore the nature of creativity as it drives problem solving.*

### **Week One:**

Flex of the Day: Ongoing student-lead FODs

Curiosity Conversations Check-in:

Five to ten minute check-in this week to get updates from students, offer assistance and motivation.

### [Brainstorming around climate change](#)

Designed to introduce the topic of climate change to the work of the course this activity will focus on the importance of brainstorming and help students familiarize themselves with the process of extended brainstorming.

### [Introduction to Climate Change Poster Project](#)

This is the major work of this unit. Working in teams of 2-4 students will unpack the subproblems related to climate change and its local impact in Evanston, IL. The posters will be printed and displayed for a poster sharing session (which will take place during unit three).

### [Collaboration vs Cooperation Activity](#)

These activities are designed to spark discussion about collaboration and cooperation and the differences between the two. Many students will have always used these two words interchangeably. After these activities and follow up discussions, students will be able to articulate the differences between collaboration and cooperation. They will be able to identify when each would be useful and some may be able to identify their own strengths and weaknesses in the area of collaboration.

## **Week Two:**

Flex of the Day: Ongoing student-lead FODs

### [Poster Session With Michelle Paulsen](#)

Michelle Paulsen of Northwestern University specializes in science communication. In particular Ms. Paulsen works with graduate students on developing their posters for academic conferences. Ms. Paulsen will be working with the STEAM DTI students for one day to help them plan their posters.

On-going work on posters: [Data Visualization workshop](#)

Ropes Course (team building)

## **Week Three:**

Flex of the Day: Ongoing student-lead FODs

### [Poster Critique session:](#)

Students will engage in discussion about the differences between criticism and critique BEFORE offering critiques of each others posters.

### [Curiosity Conversations Meeting](#)

Students will share their reflections from engaging in curiosity conversations.

On-going work on posters:  
Posters Due for printing (presentations will occur during unit 3)

### Unit 3: Innovation at the Intersection

*In this unit, students will explore the intersection of each of the five STEAM disciplines. They will evaluate the benefits of the intersection of different fields and schools of thoughts, as well as value added to diverse project teams. Through these investigations, students will analyze and challenge their own skill sets, interests, and paradigms.*

#### Week One:

Flex of the Day: Ongoing student-led FODs

[Process Mapping](#) (The following activities can be completed in any order that makes sense for the school schedule:

[S - Science process mapping](#) involves investigating the scientific method through a bit of drama and fun. We will conduct an absurd experiment testing how objects fall while posing wild hypotheses.

#### [Introduction to Individual Passion Project](#)

The individual passion project will allow students to investigate an area of personal interest. Students will perform a “deep dive” and investigate their topic. They will uncover each of the STEAM disciplines and the roles they play in the topic of interest. Students will contact professionals and experts as well as read and web search. Students will also make recommendations about opportunities for more involvement from disciplines.

[T - Technology process mapping](#) The class will model the method of scrum/agile (a common workflow in tech development). We will use this workflow to build scale models of a city!

[E - Engineering process mapping](#) The class will explore the design process while building objects for their assigned superhero in the game, “The Extraordinaires”

[Book Club](#) Meeting: With Snack and Tea, students will share their thoughts and reflections on the books they read. We will use this meeting to generate a list of recommended (and not) books and other materials for the class.

#### Week Two:

Flex of the Day: Ongoing student-led FODs



Ongoing work on individual passion project

Process Mapping Continued:

[A - Art process mapping](#) The class will be commissioned to create a work of art for a local elementary school.

[M - Math process mapping](#) The class will explore the mathematical problem solving process by working on solving a Rubik's cube.

Poster Session with invited community members

[How to Cold Contact](#)

Brief discussion on how to reach out to people you don't know but who you want information from!

### **Week Three:**

Flex of the Day: Ongoing student-led FODs

Ongoing work on individual passion project

[What makes an exciting talk?](#)

The class will discuss what makes an exciting talk!

[Meeting with PATH](#)

We will be meeting with Taj Munson. Taj works at Path ([www.path.org](http://www.path.org)). His role is assembling teams of specialists and facilitating the team's progress as they work to solve some of the world's most pressing problems. In his work he must address issues of collaboration, failure and identifying the true nature of a problem.

\*\*\*\*\*BEGIN UNIT 4:

As the students continue their work independently on their passion projects, we will begin unit 4.

### **Week Four:**

Flex of the Day: Ongoing student led FODs

Individual Passion Project Rehearsal

\*\*\*\*\*Continue unit 4

Individual Passion Project Sharing and filming

## Unit 4: Introduction to Design

*In this unit, students will be introduced to the design process. After a series of smaller challenges, the students will complete a design project for a specific client based on a challenge from the Illinois R&D STEM Learning Exchange. Modeled after the work of Motorola Solutions, teams will design a new technology for first responders. They will consider the perspectives and needs of multiple user groups, connecting with local teams who work on disaster preparedness and crisis management. This unit will model the processes and expectations for students independent second semester projects.*

### Week One:

[Redesign your partner's gift-giving experience](#) (1 day)

In this one-day session, students will be introduced to the design thinking process.

[Redesign your partner's wallet](#) (2 days)

This two day session expands upon the one day sessions and invites students to be more flexible with their use of the process. This session also pushes deeper into the notion and ethos of prototyping

Individual Passion Project Rehearsal (1 day)

Individual Passion Project talks in the little theater! (1 day)

### Week Two:

3 -day [sketching Workshop](#)

Under construction! This workshop will be led by Bill Simos, graphic design teacher at ETHS. Major goals include: basic sketching techniques, sketching as brainstorming, and storyboarding.

Begin [Prototyping Week](#) (5 days)

Inspired by the course offered through Acumen+ and IDEO, this week will introduce students to four kinds of prototypes: a product, a system, an environment, and a service. This week is intended to build of the students early understandings of prototypes and encourage them to see prototyping as a method of learning more about the user and potential solutions.

### Week Three:

[Empathy through Theater with Byron Stewart](#) (2 days)

This workshop will introduce students to the use of improv and theater as a method on empathizing with users and defining the problem. This workshop will also serve as the launch for the ETHS challenge.

### Week Four:

### [ETHS Design Challenge](#) (5 days)

Students will complete a design sprint in 5 days. Students will receive the challenge to find a way to increase use of and understanding of #wildkitway (an ETHS branding tool). Students will design and conduct research, brainstorm, ideate, create prototypes, develop pitches, and use feedback to create additional prototypes.

### **Week Five:**

Begin [Uptake Challenge](#) or [Emergency Response Challenge](#)

This challenge will serve as the last challenge of semester one. Students will experience a longer term project with real clients from the community (either Evanston Police and Fire departments OR Uptake Data) Students teams will be responsible for all phases and planning. The instructor will facilitate daily check-ins

### **Week Six:**

Continue [Uptake Challenge](#) or [Emergency Response Challenge](#)

### **Week Seven:**

Continue [Uptake Challenge](#) or [Emergency Response Challenge](#)

### **Week Eight:**

Continue [Uptake Challenge](#) or [Emergency Response Challenge](#)

### **Week Nine:**

Final demonstrations!

## **Semester 1 Final Exam: Demonstrations of prototypes from Emergency Response or Uptake Challenge**

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### **Second Semester Capstone Project:**

Overview, goals, tasks and timeline

Description: The second semester project will provide a capstone opportunity for students teams. The purpose of the capstone is to allow students the freedom to chart their own path, make mistakes and back-track as needed, and experience project management in an authentic context. Because the project will span only five months, student teams might not achieve a “final product”. The focus of this particular capstone will be the process. Student teams will focus on process over product in order to experience authentic design contexts. Student teams will conduct community based research, gather user feedback, seek critique and engage in lengthy

brainstorming sessions. The topic selection will be based on student interest and teams will be formed based on self-selection.

Goals: Student teams will be able to define their own project timeline. Student teams will be able to articulate the design process and describe their adaptations of the design process. Student teams will fully execute each phase of the [Design Thinking process](#). Student teams will collaborate effectively and will be able to arbitrate differences of opinion (with instructor assistance as needed). Student teams will produce a written project brief ([sample](#)). Student teams will create a [final demonstration](#). Student teams will synthesis feedback from instructors, community members and each other in order to improve their process and their designs.

Assessments:

Proposal and critique with members of the community

Project brief and design crit after phase one with members of the community

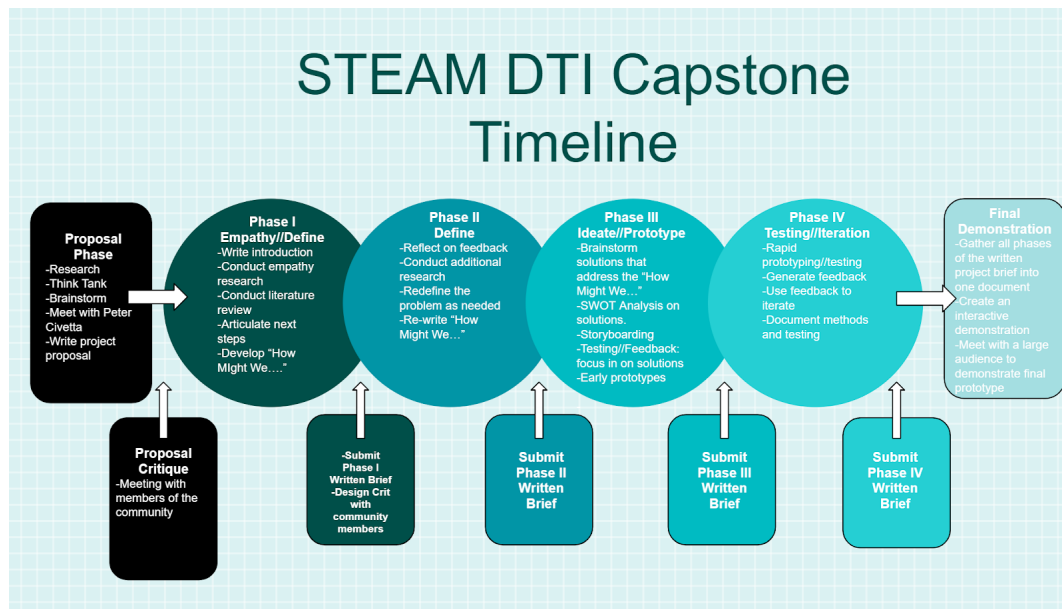
Student teams will maintain a daily journal of accomplishments and next steps

Weekly (or more as needed) check-ins: Students will present a timeline for both immediate needs and future needs, share open questions, request materials or other needs from instructor, share documentation of meetings with community members or user testers

Student teams will submit a written brief summarizing each phase of the project ([rubrics](#)).

Student teams will create a final demonstration

Timeline:



**Semester 2 Final exam: Demonstrations of final prototypes developed, and collection of additional user feedback.**

## APPENDIX B: Major Assignments and Activities

Assignment: Climate Change Poster Project | **STEAM DTI 2018-2019**

### **"Climate Change: Defining the problem on a local level"**

Your task as a team is to delve deep into a problem related to climate change. YOU ARE NOT ATTEMPTING TO SOLVE THIS PROBLEM (yet). You will analyze the problem in order to truly unpack it and drill down to the heart of the problem as well as the true impact of the problem. You will document your process in an informational, research poster.

With your team, comb through the initiatives and search for claims made in both the [Chicago Climate Action Plan](#) and [Evanston Climate Action Plan](#). Both websites have robust reports, progress measures, and data sets available

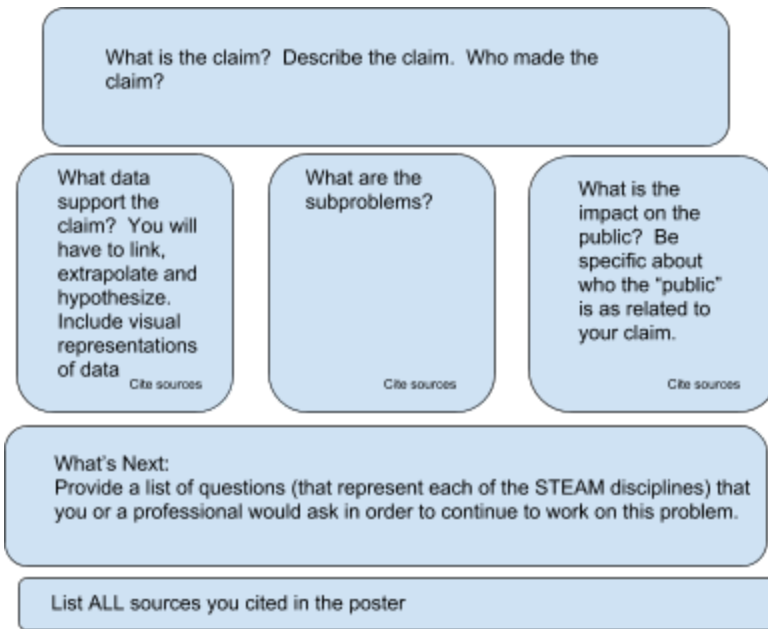
As a team choose a claim that you are going to research, reflect upon and present as a [poster](#).

1. Investigate this claim and offer evidence to support or refute the claim (include visual representations of data)
2. Explore the impact on public safety, communication, public health etc.
3. Deconstruct the problem addressed into subproblems that connect to the larger issue
4. Brainstorm a list of questions from the five STEAM disciplines that you OR a professional in one of these disciplines would ask as part of considering this problem and working on a solution.
5. Include citations for all data and images you use that are not created by our team!

What should my poster look like?

That's entirely up to your design process. We will look at poster design as a group.

Here is what should be contained within your poster:



Consider visual appeal!

Timeline For implementation:

September 13: Topic choice and team creation

September 14, 15, 18: Research CAPs in teams, define a problem area of interest

September 19: Share your team's area of interest, further investigate area of interest

September 20: [Data visualization workshop](#)

September 21: NO SCHOOL

September 22: [Poster design workshop](#)

September 25,26: Poster work

September 26: Rough draft of poster to be shared for a crit session

September 27,28: Finish posters

September 29: POSTER SENT TO PRINTER!

October 7th: Poster session!

## Assignment: Individual Passion Project | STEAM DTI 2018-2019

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4 Model with mathematics.

CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.

CCSS.MATH.PRACTICE.MP6 Attend to precision.

### STEAM DTI Individual Passion Project:

Exploring the interdisciplinary nature of an event, organization, or issue you're passionate about.

**Purpose :** Through this project you will explore how the STEAM disciplines interact within a topic of your choice. You will be researching, reaching out, analyzing, and reporting out on your topic... Choose wisely. Your topic must be robust enough to have the information you need, accessible enough to offer you individuals to reach out to (via email or phone call) and global enough to offer you the chance to expand your investigation. This project will be a deep dive into something you already feel passionate about.

**Phase I: CHOICE** Choose a topic of study that is of great personal interest to you. Identify the primary field of study which is used for problem solving in this topic. This is an assignment posted in the google classroom.

**Phase II: INVESTIGATION** Brainstorm a substantial list of questions about your topic. Investigate and connect with people and organizations both locally and globally which are related to your topic and field. Pick four people to contact via email. A check in for phase II will be posted in the google classroom.

### Phase III: EXPANSION // ANALYSIS

Using what you uncovered in phase II, examine and analyze the intersection of the STEAM disciplines within the field. List and provide detailed answers to the questions:

- Where is the art in my topic?
- Where is the math in my topic?
- Where is science in my topic?
- Where is the engineering in my topic?
- Where is the technology in my topic?
- How do these disciplines interact with each other? Where is there overlap?
- What does the future look like for your topic? Highlight the areas of intersection.
- How would your topic benefit from additional or improved collaboration between the STEAM disciplines?

A check in for phase III will take the form of a google slides “scrapbook”.

#### **Phase IV: EXTRAPOLATION and REPORT-OUT**

Research talk (Think TED Talk style). You will be filmed in the Little Theater sharing your engaging deep dive into a topic you are passionate about. Present your work in a way that engages the audience. DO NOT read your slides! We will spend class time working on how to give engaging talks to varied audiences. We will elaborate on this as the time draws closer but for now, keep in mind these [four guiding principles from Chris Anderson](#):

1. Focus on just one key idea to share
2. Give your listeners a reason to care
3. Build your idea piece by piece out of concepts your audience understands
4. Make your idea worth sharing

**Grading:** Students will be evaluated based on check-ins that will occur after each phase of the project

Phase I	Phase II	Phase III	Phase IV
Check in date: 10/20	Check in date: 10/23	Check in date: 10/30	Rehearsal date: 11/1 Filming date: 11/3
Complete the google doc for phase I and submit to Klyn. Share your google slides scrapbook	Complete the google doc for phase II. Submit and receive approval for drafts of all cold emails.	Complete your google slides scrapbook for sharing with the group.	Your talks will be posted to the STEAM DTI social media page and shared with the ETHS community.

#### **Sample Project: By Mrs. Klyn**

**Refer to the project below as a rough draft of a project.**

**What follows IS NOT A COMPLETE PROJECT but rather an outline of what a complete project would look like when all the questions were answered, angles explored and research analyzed and prepared for sharing!**

<b>Phase I</b>	<p><b>Topic Selection:</b> The Chicago Marathon</p> <p>I chose the Chicago Marathon because <u>I am passionate about running</u>, ran the marathon this year and already have quite a sense of how marathons operate.</p> <p><b>Primary Field of study:</b> Engineering (Systems)</p> <p>I believe the primary field of study is Systems Engineering because the Chicago Marathon is a huge event that requires a lot of coordination and organization.</p>
<b>Phase II</b>	<p>-Read articles about the Chicago marathon. Explore the Chicago Marathon Website. Read the magazine published by the Chicago marathon. Read/watch news coverage of the marathon from this and past year. Explore the 2007 Chicago Marathon (because it was a disaster)</p>



	<p>-Questions to ask: Who organizes the marathon? What is involved in planning the Marathon? How do they close the roads? How far in advance do they start planning? How do they get people to sign up? How do they keep track of runner's times? What if there is an emergency? How do they get sponsors? How do they protect runners and spectators? How do they organize the volunteers? What is involved in the marketing? How has the 2007 Chicago Marathon influenced the direction of the marathon since the disastrous run?</p> <p>Organizations/Stakeholders to research: Bank of America (sponsor) Chicago Marathon Organizers, Chicago Police, Chicago Fire Department, Chicago City Council, Chicago Area Runner's Association, Nutritionists, Sponsors (Gatorade, Abbot, American Airlines) Exercise Scientists, Athletic Trainers, CTA, Metra, Parking Lots, Chicago Parks Department, Streets and Sanitation Department, Local/National News Organizations, Timex (Official TimeKeepers), Entertainment Company, Food Suppliers, Volunteers.</p> <p>-Contact Relevant individuals: Chicago Marathon Director (attempt to reach, but prepare a back-up, perhaps a staff person would work here). Person at CPD in charge of marathon safety. Volunteer coordinator. An on site doctor. A volunteer. Entertainment Coordinator. Person in charge of clean up. Person in charge of providing on site sanitation. Someone at Bank of America's sponsorship department.</p>
<b>Phase III</b>	<p>Where is the science in planning the marathon? Athletic trainers, doctors, Where is the engineering? Designing the clothing and shoes. Organizing runner start and finish. See Phase 2 for more here, but encourage students to expand and incorporate more information.</p> <p>Where is the technology? Chip timing, video and photography</p> <p>Where is the art? Communication. Design (clothing, medals, signage etc). Musical entertainment. Also data visualization, signage, maps, sound</p> <p>Where is the math? Tracking runners, comparing race data from year to year, financial matters (how do you pay for everything? How do you predict how much you will need to charge runners?) Route planning and mapping.</p> <p>Connections to explore:</p> <ul style="list-style-type: none"> <li>- Registration process requires technological solutions (How do runners actually register) as well as artistic solutions (Aesthetics of the website) also</li> <li>-Planning aid stations requires science (how much water to put where, when to provide food, what kind of food to provide?) , systems engineering (how do we get volunteers to and from?), art (How do the runners know they are approaching an aid station?)</li> </ul> <p>GREAT example of the art here. You really want to be careful and strategic, pushing back against the notion that art is "only" aesthetics. Push yourself to think about and</p>

	<p>articulate the purpose of the art. E.g. the visual design here of signage gives people vital information.</p> <p>-The starting line: Art (What music is played?, are there fireworks?), Technology (Tracking chips for runners) Engineering (Logistics of bathroom use), Math (How many runners in each starting wave for optimal spacing).</p> <p>-What does the future look like for the Chicago Marathon?</p> <p>-How will the collaboration between the STEAM fields improve the marathon experience?</p> <p>-Where are there areas that could benefit from additional collaboration between disciplines?</p> <p>For these last three questions, give examples of each:</p> <p>Possible things to consider: clothing, chips, smartwatches, safety improvement, tracking that connects the runner to a particular set of supporters (e.g. where is mom now?), data provided to runners as they progress, what about participants with disabilities?, think about a variety of users related to the Marathon - what could improve their experience and how would the intersection of disciplines come together to help.</p>
<b>Phase IV</b>	<p>Prepare a sweet TED-style Talk about the Chicago Marathon with cool pictures, video, graphs, charts, stories, quotes from interviews etc.</p>

## Assignment: Emergency Response Challenge | STEAM DTI 2018-2019

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4 Model with mathematics.

CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.

CCSS.MATH.PRACTICE.MP6 Attend to precision.

### **Introduction: Evanston Emergency Preparedness**

Preparing for and responding to emergencies is a critical task. The responsibility falls on a variety of government agencies at the federal, state, county, and local levels. In emergencies, including man-made and natural disasters, the entire community become key stakeholders in the crisis. Emergency management involves the dynamic processes of risk assessment, preparation, response, mitigation and recovery.

The City of Evanston has [several departments](#) that are responsible for emergency management, including Police, Fire, and Health and Human Services. While the entire city government has a role in emergency management, it is these departments' primary responsibility. As our world changes, the potential for new threats emerge as possibilities that may face the community. Emergency management is complex, but also must be nimble, flexible, and thorough in the planning for and responding to a wide range of possible scenarios.

When a disaster occurs across the country or the world, the resulting responses are analyzed and evaluated in order to integrate new information, research, and best practices into existing plans. As the world changes, new threats and opportunities emerge in the field of emergency management. Further development of communication systems, applications, sensors, and tools to help mitigate the effects of disasters and to save lives in emergency situations, depends on three key components: accountability, preparedness and collaboration. ([Reference](#)) For example, technology has revolutionized the lives of people across the globe and has become instrumental in assisting people in emergency situations. The proliferation of technology, mobile phones, and social media have helped to warn people of and to save lives during and after natural disasters; disease outbreaks; attacks; and accidents such as motor vehicle, industrial, chemical spills, and fires. Innovation shapes our everyday lives, including the ordinary and extraordinary events that occur in our community.

### **The Evanston Emergency Management Challenge**

The City of Evanston is looking to you as citizens, and the next generation of innovators, to help recommend new approaches in emergency management. Ordinary citizens like you are often the new first responders, often equipped with a communication device that allows you to pinpoint the location, take pictures or video, and spread an alert via social media. Consider the potential power and responsibility that engaged citizens across our diverse community hold in the areas of risk

assessment, preparation, response, mitigation and recovery. The City hopes to learn from your insights and experiences as you bring fresh ideas for innovation in emergency management.

***The design challenge is for you to investigate and recommend an innovative design solution that you might develop to help save lives and keep people safe in emergency and disaster situations.***

**Your Semester 1 Final Exam will be a formal presentation of your process.**

In order to investigate this problem, you will need to consider the following questions:

### **I. Researching the Problem**

What are the needs and challenges?

- What are different types of emergencies that are possible in Evanston?
- What are different types of disasters that are possible in Evanston?
- What are different agencies, departments, and stakeholders in Evanston related to disaster preparedness and emergency management?
- What are the needs of various types of first responders? Consider what information each might need, with whom they need to communicate, and what types of action is required to address disasters?
- How are different stakeholders (user groups) involved in risk assessment, preparation, response, mitigation and recovery?
- How could you use storyboards to document and describe various experiences with emergencies and disasters? Consider timelines before, during, and after events.

When considering emergency management, what are possible questions that arise from each of the STEAM disciplines?

- What questions would a scientist ask about emergency management?
- What questions would a technologist ask about emergency management?
- What questions would an engineer ask about emergency management?
- What questions would an artist ask about emergency management?
- What questions would a mathematician ask about emergency management?

What problem would your team like to target for innovation?

- Is there a particular emergency or disaster on which you would like to focus?
- Who is your user group that your team will target with the innovation?
- What problem or question would your group like to address?

- What are the relevant sub-problems that you will need to address?

## II. Defining the Problem

How can you benchmark current solutions for a particular problem?

- What is the current process used to address your target problem?
- What works about that approach? What are the issues and pain points?
- What does your team see as opportunities for innovation?
- What unknown information does your team have about the problem and the current solution?
- What solutions are currently available, perhaps in other communities or outside the field of emergency management?

What are your parameters relevant to innovating in this space?

- What are the criteria for a successful innovative solution?
- What are the constraints around a possible solution?
- What are the requirements for innovation?
- To what extent would current solutions meet your criteria for a successful solution?

## III. Ideation

What are possible innovative solutions?

- What possible solutions can you brainstorm around EACH of the requirements?
- How can you categorize and combine features of possible solutions in order to maximize the possibilities for potential solutions?
- How can you devise and implement a procedure for narrowing possible solutions?
- How can you prioritize constraints, requirements, and criteria in order to evaluate potential solutions?
- How can you document all of your ideas, including those not chosen and the rationale?

## IV. Problem Solving Approach

How would the different STEAM disciplines approach this problem?

- What questions would each of the disciplines ask about your target problem? About your solution? About your process?
- How would the problem-solving approach differ depending on which STEAM lens you use in your process?
- Which discipline is most relevant for your group to use as the primary approach, lens, or process for this problem? Justify your choice.
- What would be the secondary and tertiary approaches that would be relevant?
- Where do you see the intersection of disciplines in the problem and your approach?

What is your timetable for innovation, iteration, and evaluation?

- What research and discovery does your team need?
- What are the parts of your design cycle that you will implement and test?
- How will you test, analyze, and evaluate success in your design?

- What are the deliverables that are necessary for your team to develop for your client and stakeholders?
- How will you leave ample room in your timeline to allow for and adapt to the unexpected?

What can you extrapolate from your research and design?

- What logistical challenges do you see in your design and solutions?
- What is the availability of relevant technology and/or infrastructure related to potential solutions?
- What broader implications and applications are uncovered in your design process?
- What might be the costs associated with developing, implementing, and potentially marketing your solution?
- What are the tradeoffs that come with your solution? E.g. privacy issues, cost, time, additional personnel or training needed?
- What governmental regulations and legal issues might come up in your design and implementation?
- To what extent are these questions within the scope of your research and design?
- What open questions does your solution leave that would require further investigation?

## Potential Resources

### Local Emergency and Disaster Resources

- [City of Evanston](#)
- [Chicago and Northern IL Red Cross](#)
- [Cook County Department of Homeland Security & Emergency Management](#)
- [Cook County Department of Public Health](#)
- [Northwestern Safety & Security](#)
- [Northwestern Campus Emergency Preparation & Response](#)
- [Northwestern Emergency Response Framework](#)
- News articles about [training for emergency management](#)

### Federal Emergency and Disaster Resources

- [Centers for Disease Control and Prevention](#)
- [FEMA](#)
- [Illinois Emergency Management Agency](#)
- [Ready.gov](#) and [Ready Illinois](#)
- [The Federal Communications Commission site for first responders](#)
- Government website resources for first responders such as [firstresponders.gov](#)
- Companies such as [Motorola Solutions](#) innovate in emergency management

## Capstone: Overview, goals, tasks and timeline

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4 Model with mathematics.

CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.

CCSS.MATH.PRACTICE.MP6 Attend to precision.

Description: The second semester project will provide a capstone opportunity for students teams. The purpose of the capstone is to allow students the freedom to chart their own path, make mistakes and back-track as needed, and experience project management in an authentic context. Because the project will span only five months, student teams might not achieve a “final product”. The focus of this particular capstone will be the process. Student teams will focus on process over product in order to experience authentic design contexts. Student teams will conduct community based research, gather user feedback, seek critique and engage in lengthy brainstorming sessions. The topic selection will be based on student interest and teams will be formed based on self-selection.

Goals: Student teams will be able to define their own project timeline. Student teams will be able to articulate the design process and describe their adaptations of the design process. Student teams will fully execute each phase of the [Design Thinking process](#). Student teams will collaborate effectively and will be able to arbitrate differences of opinion (with instructor assistance as needed). Student teams will produce a written project brief ([sample](#)). Student teams will create a [final demonstration](#). Student teams will synthesis feedback from instructors, community members and each other in order to improve their process and their designs.

### Assessments:

Proposal and critique with members of the community

Project brief and design crit after phase one with members of the community

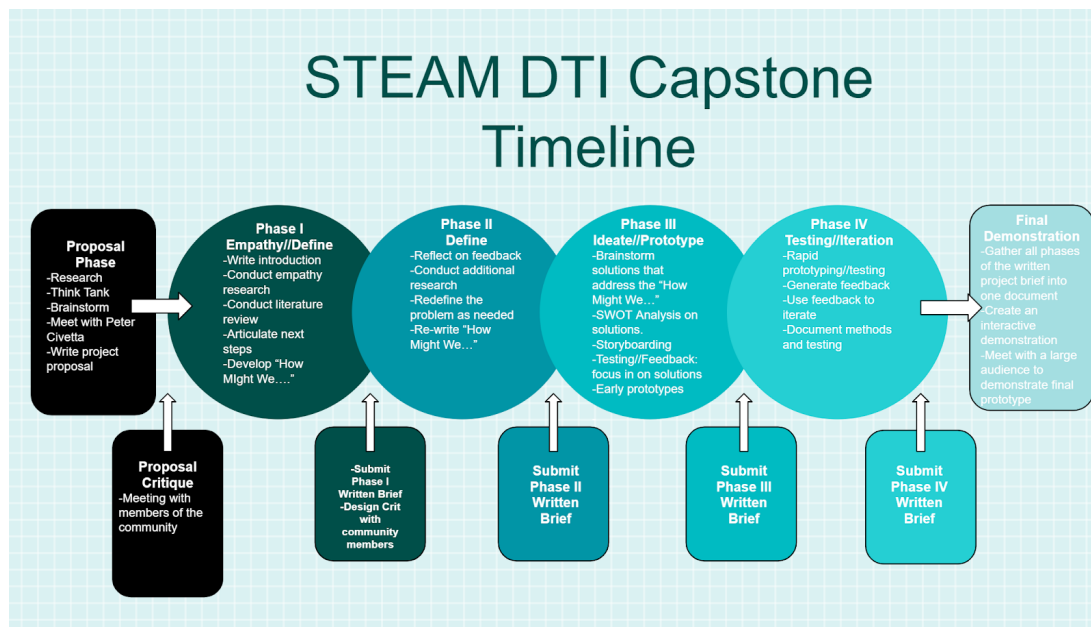
Student teams will maintain a daily journal of accomplishments and next steps

Weekly (or more as needed) check-ins: Students will present a timeline for both immediate needs and future needs, share open questions, request materials or other needs from instructor, share documentation of meetings with community members or user testers

Student teams will submit a written brief summarizing each phase of the project ([rubrics](#)).

Student teams will create a final demonstration

### Timeline:





## APPENDIX C: Course Resources

The following references were used as frameworks, inspiration or resources for the STEAM DTI curriculum and materials.

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